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COMPREHENSIVE EVALUATION OF ENERGY CONSERVATION MEASURES

MATHEMATICA, INCORPORATED

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

MARCH 1975

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COMPREHENSIVE EVALUATION OF ENERGY CONSERVATION MEASURES

FINAL REPORT

Prepared for

U.S. Environmental Protection Agency
Office of Planning and Evaluation
Washington, D.C.

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COMPREHENSIVE EVALUATION OF ENERGY CONSERVATION MEASURES

by

Dilip R. Limaye
John R. Sharko
Jeffrey P. Price
Joseph A. Orlando
MATHEMATICA, INC.
Regional and Environmental Studies Group

and

Frank Oelschlager
John Wander
Gail Gibson Hunt
Thomas Wright
Len Schossler
Arthur Hyder
PEAT MARWICK MITCHELL AND CO.

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Project Officer
Margaret J. Tifft
Office of Planning and Evaluation

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*bound separately

ACKNOWLEDGEMENTS

This report was prepared by MATHEMATICA, Inc. for the Environmental Protection Agency under contract No. 68-91-2445. It combines work performed by MATHEMATICA with that done by PEAT, MARWICK, MITCHELL under contract No. 68-01-2440. The report describes a comprehensive evaluation of selected energy conservation measures in the residential, industrial, commercial, transportation and electric power generation sectors. MATHEMATICA was responsible for the review and comprehensive bibliography of proposed measures and previous analyses, and the determination of "maximum technologically feasible" energy savings resulting from each measure. The calculation of achievable energy savings and impacts was performed by PEAT, MARWICK, MITCHELL and Co. (PMM&Co.). MATHEMATICA then integrated the two reports into this final report.

The work performed by PEAT, MARWICK, MITCHELL was directed by John Wander and Frank Oelschlager. Team members included Gail Gibson Hunt, Thomas Wright, Len Schossler and Arthur Hyder. The MATHEMATICA effort was performed under the overall direction of Dilip R. Limaye. The project team members included John R. Sharko, Jeffrey P. Price, and Dr. Joseph A. Orlando. Significant contributions were also made by Ms. Margaret Tifft of the Environmental Protection Agency. In addition, consulting support was provided by Dr. Harry Brown, Dr. Bernard Hamel, Lawrence Spielvogel and Robert LeMay.

"The growing concern about energy is inevitable since energy is at the base of all life, of all activity, of all industry. Energy is precious. Save for the sun, it is exhaustible at widely different rates of use. It is accessible only given certain technological knowledge. It can be wasted; and in no other highly industrialized country is the waste greater and more obvious than in the United States."[1]

---

[1] Oskar Morgenstern, in Energy Policy Evaluation, edited by D. R. Limaye, Lexington Books, August 1974.

I. EXECUTIVE SUMMARY

A. BACKGROUND

To meet environmental standards and accomplish energy conservation simultaneously requires development not only of measures that would reduce energy consumption and environmental pollution, but also the mechanisms by which the measure can be implemented with minimum negative impacts. At the present time there are a large number of possible conservation measures. However, while numerous studies on energy savings and impacts have been developed, it is not clear which measures, if implemented, would most effectively serve Federal, state and local government objectives.

In the spring of 1974, the Environmental Protection Agency (EPA) identified a need to evaluate various energy conservation measures, both in terms of potential energy savings and environmental, economic and social impacts. Three separate research questions were formulated, each resulting in a separate but complementary study. These questions were:

- what is the maximum technolgically feasible energy savings potential for various energy conservation measures?
- what is the "achievable" savings from each energy conservation measure, taking into account such factors as public compliance and implementation lead time, and what would be the relative economic, environmental and political/institutional impacts of these measures, if implemented?
- what would be the macroeconomic impacts of reducing the historic demand growth rate?

B. OBJECTIVES

This report summarizes the approach and findings of the studies undertaken to address the first two objectives.[1] The objectives of the studies were to:

- develop a replicable evaluation methodology for government agencies at the Federal, state and local levels to review, evaluate and rank energy conservation measures with respect to their specific goals and objectives; and
- test the methodology on a selected set of energy conservation measures and implementation strategies at the national level.

C. SUMMARY OF APPROACH

The following is a summary of the methodology and specific tasks in the two studies:

- compilation of a comprehensive bibliography of energy conservation studies and a review of these studies to develop a complete list of conservation measures which are technologically feasible in the 1976-1990 time frame;
- identification and selection of approximately thirty measures for further study. (The measures were approximately equally divided among the energy sectors and are listed in Figure I-1);
- detailed evaluation of each of the thirty measures in order to estimate the "maximum technologically feasible" energy savings potential -- both on a "per unit" basis and on a total sector basis;

---

[1] A study to estimate the maximum technological savings was performed by MATHEMATICA, Inc. An estimation of the achievable savings, method of implementation and impacts of each measure, as well as an evaluation and ranking of the measures was performed by Peat, Marwick, Mitchell & Co. The two studies were performed in parallel, with significant interaction among the two project teams and the EPA project officer.

FIGURE I-1

SUMMARY OF SELECTED CONSERVATION MEASURES AND IMPLEMENTATION STRATEGIES

SECTOR	SERIAL NO.	CONSERVATION MEASURE	IMPLEMENTATION STRATEGY
RESIDENTIAL	R-1	Increasing the efficiency of residential space heating	mandatory factory installation of flue heat recovery devices on all new furnaces (under FTC or FEA regulation) and annual cleaning and maintenance of these furnaces (prompted through means such as public appeal and education).
	R-2	Increasing use of residential insulation and increasing storm window and door retrofitting	a) upgrading FHA/VA minimum standard for insulation in new housing construction, b) providing Federal and/or state income tax benefits for costs incurred in retrofitting insulation and storm windows and doors in existing dwellings.
	R-3	Implementing minimum efficiency ratings and standards on new major appliances	establishing federal standards under FEA or FTC regulation.
	R-4	Changing thermostat settings	voluntary means such as public appeal and education.
	R-5	Use of solar energy and/or heat pumps for heating and cooling	allowing a tax credit for accredited solar energy/heat pump systems.
INDUSTRIAL	I-1	Increasing the efficiency of direct heat and steam raising	Not considered*
	I-2	Increasing efficiency of energy intensive processes	Not considered*
	I-3	Increased recycling of energy intensive materials	federal legislation supplying subsidy grants
	I-4	Reduced use of packaging	federal regulation
	I-5	Decreased use of non-returnable bottles	eliminate nonreturnable beverage containers through federal regulations
	I-6	Use of Total Energy Systems	promote total energy systems use in industrial plant design through tax credits
	I-7	Increase use of natural fertilizers	voluntary means (free market mechanism)
COMMERCIAL	C-1	Reduction in ventilation air quality standards	modification of local building code regulations
	C-2	Reduction in air flow within buildings	modification of local building code regulations
	C-3	Adjustments in temperature control	Promote voluntary adjustments by season, day of week and time through public appeal and education
	C-4	Increased use of task lighting	modifications of local building codes, regulations.
	C-5	Use of Total Energy Systems	tax credits for use of such systems
	C-6	Use of Solar Energy/Heat Pumps	tax credits for use of such systems

* These measures were not considered in the Peat, Marwick and Mitchell study of impacts and evaluation and ranki

** This measure was not evaluated because it can be considered as already implemented.

FIGURE I-1 (continued)

SECTOR	SERIAL NO.	CONSERVATION MEASURE	IMPLEMENTATION STRATEGY
TRANSPORTATION	T-1	Increased use of car pools	giving carpools privileges not afforded to single car commuting, such as lower cost and preferential parking, use of bus lanes (3 or 4 riders required per car), and elimination or reduction of bridge or tunnel tolls.
	T-2	Increasing automobile efficiency	a) voluntary increased maintenance; b) voluntary tune-ups; c) mandated use of radial tires; d) mandated energy efficient aerodynamic design of automotive vehicles; and e) mandated federal engine efficiency standards per weight of vehicle.
	T-3	Increasing use of piggyback and containerization for inter-city freight	encourage highway users to utilize the more fuel-efficient alternatives of container or trailer on flat car (COFC or TOFC), through regulatory avenues, legislated economic incentives, and voluntary public cooperation.
	T-4	Modal shifts in inter-city passenger transportation	increasing the frequency, range, and quality of service through legislative change and economic incentives.
	T-5	Increased use of bus transit	better and faster service and economic incentives including: greater operating frequency and area coverage; improved routing to meet commuter needs; use of exclusive bus lanes; subsidized transit fares; and reduction in downtown parking through higher parking taxes.
	T-6	Improved scheduling and load factors for air transportation	Not considered*
	T-7	Reduced speed limits on highways	Not considered**
POWER GENERATION	P-1	Direct firing of solid waste for power generation	state and federal subsidy for purchase and depreciation costs of plant equipment.
	P-2	Pyrolysis of solid wastes for production of fuel	state and federal subsidy for purchase and depreciation costs of plant equipment.
	P-3	Bioconversion of solid wastes	state and federal subsidy for purchase and depreciation costs of plant equipment.
	P-4	Use of wind energy as a supplement power source	program of federal grants to assist in research and development problem-solving combined with loan assistance and subsidies.
	P-5	Recovery of waste heat from power generation.	federal and/or state subsidies.

* These measures were not considered in the Peat, Marwick and Mitchell study of impacts and evaluation and ranking.

** This measure was not evaluated because it can be considered as already implemented.

- postulation of implementation strategies for each conservation measure;
- development of implementation and impact evaluation criteria;
- development of evaluation and priority ranking methodology;
- evaluation and ranking of the conservation measures in terms of:
  - implementation feasibility
  - potential energy savings
  - direct economic, social and environmental impacts

D. IDENTIFICATION OF MEASURES AND ESTIMATION OF MAXIMUM TECHNOLOGICALLY FEASIBLE SAVINGS

The first step in the study was a detailed literature search and the preparation of a comprehensive bibliography on energy conservation. Since a significant amount of additional conservation research is currently being performed (with little or no published material), contacts were made with a large number of individuals and organizations to get the benefit fo their current efforts.

Based on the review of this literature, the vast array of conservation measures was catalogued.[1] This comprehensive list was then used as a basis for selection of thirty conservation measures for further study. The general criteria used for selection were:

- availability of data on the effects of the measure;
- estimated potential energy savings; and
- feasibility of implementation during the time frame of the study (1976-1990), including the technological, political and institutional considerations.

---

[1] MATHEMATICA, inc., 1974, and also in Appendix G.

A comprehensive review and synthesis of all the information relevant to each measure was then performed. The estimation of the impact of any conservation measure on total energy consumption was based first on a micro-level and then on a macro-level analysis. The micro-level analysis involved the determination of the effects of adopting the measure on individual energy consuming units, whereas the macro-level analysis aggregated these effects to the total sector taking into account factors such as growth trends, government policy and institutional factors. Meshed together, estimates of maximum energy savings potential were made based on technological and non-technological issues simultaneously for both per unit and total savings for each measure.

It is important to emphasize that the study concentrated on estimating the maximum feasible energy savings which could result from overall implementation of the measure nationally.

The limited resources and time available for performing the study imposed certain assumptions and limitations which constrained the study.

1. The savings were estimated from a Baseline Projection (see (Appendix A) which was developed from the historical data in the MATHEMATICA Energy Data Base and assumed a continuation of past trends.
2. The savings were estimated on a primary energy basis, i.e. electricity was converted back to the fossil fuels and hydro/nuclear energy used for power generation.
3. The per unit savings were assumed to apply to all relevant units throughout the United States.

4. No regional analysis was performed. Estimates were made at the national level only.
5. While electricity and fossil fuels were separated in the analysis, the three major fossil fuels (coal, oil and gas) were analyzed together in the residential, commercial and industrial sectors.
6. Only those measures (or technologies) which would make significant contributions before 1990 were considered.
7. Each measure was analyzed as if it were implemented by itself (independent of all other measures) and the savings from each measure were computed from the baseline projections. No attempt was made to evaluate the interaction or interrelationships of the measures. The results of the simultaneous implementation of two or more measures were, therefore, not evaluated, and is not likely to be the sum of the savings of each measure.

E. METHODOLOGY FOR EVALUATION AND RANKING OF MEASURES*

The evaluation and ranking methodology provides a systematic tradeoff analysis to enable federal, state and local government agencies to formulate energy conservation programs responsive to their specific goals and objectives. To accomplish this, the methodology provides a mechanism to tradeoff each measure's relative energy saving effectiveness against the probable benefit and disbenefit impacts that would be associated with measure implementation. The tradeoff analysis results are expressed as common based values to enable (1) comparison of each measure with each other measure for priority ranking; and (2) comparison of alternative implementation strategies for a specific measure. The methodology is comprised of three major elements: energy saving effectiveness, impacts, and a common based effectiveness/impact measure.

---

*Evaluation and ranking methodology developed and applied by PMM&Co

The first element, energy saving effectiveness, is a simple estimate of the probable energy savings, expressed in BTUs, that could be achieved by implementing a specific conservation measure. Since actual savings will be dependent upon the method of implementation, a specific implementation strategy must be postulated for each conservation measure. Conservation measure effectiveness is then estimated by first determining the maximum technologically feasible savings potential for each measure, irrespective of the implementation policy assumed, and second, applying an analysis of implementation feasiblity to the estimated technologically feasible savings to determine estimated achievable energy savings. Achievable energy savings are estimated based upon the following criteria:

- technolgical feasibility - the need for additional research and development;
- logistical feasibility - ease of siting, materials distribution and information dissemination;
- political/legislative feasibility - necessity for legislative action, existence of legal precedents and administrative governmental structures, and enforceability; and
- controversiality -- any strong positive or negative attitudinal factors.

The second element, impacts, are simple estimates of likely benefits and/or disbenefits to both the public and private sectors, assuming conservation measure implementation. Each conservation measure is individually analyzed to estimate direct impacts in each of the following areas:

- dollar impact on private industry, private consumer, and the public sector, including government and the balance of payments;
- employment impacts (jobs lost or gained);
- life-style impacts (mobility, convenience, comfort and schedule disruption),
- scarce materials or resource impacts; and
- environmental impacts on air, water, and solid waste.

The third and final element is the development of a single value to describe measue effectiveness in terms of both energy savings and impact. The value is estimated first describing the impacts associated with each measure as a single relative value on a scale of 0 to 100; second, converting energy savings to a relative value on a comparable scale of 0 to 100; and third, adding the relative energy saving value to the relative impact value to obtain a single effectiveness measure. The steps for estimating this value are as follows:

STEP 1 - Relative Impact Value

Because each type of impact is expressed in different units, e.g., jobs and dollars, it is necessary to establish a common basis of comparison. To do this, each impact is converted to a relative value on a scale of 0 to 100. This is accomplished by assigning the worst and the best values in a impact category, to zero and one hundred, repectively. Values for other measures are then assigned intermediate values as shown below:

	IMPACT	RELATIVE VALUE
Measure A	+50 jobs	100 Best
Measure B	+25 jobs	80
Measure C	-25 jobs	40
Measure F	-75 jobs	0 Worst

Each individual has different opinions of which impacts are important or unimportant. Rather than allowing the different impacts to remain equal, importance weights are developed. In this analysis, impact weights were developed by surveying the EPA Office of Planning and Evaluation (OPE). The weights developed on the basis of this survey are as follows:

IMPACT	% WEIGHT
Private industry cost/saving	11.6
Private consumer cost/saving	13.0
Government cost/saving	13.8
Balance of payment saving	7.1
Employment job gain/loss	13.8
Resource/material (qualitative)	13.0
Quality of life (qualitative)	11.6
Environment (% reduction)	16.1
TOTAL	100.0

It should be noted that the relative weights assigned on the basis of the OPE survey can easily be changed by other users of this methodology to reflect alternative priorities. In actual practice, the weights should be established only after careful consideration of the goals and objectives toward which an energy conservation program would be directed.

The scaled impact scores for each measure are multiplied by the weighting values shown above to obtain a weighted value for each impact. All of the impact values for a specific measure are added together to obtain a single impact score.

STEP 2 - Relative Energy Savings Value

Since impacts are expressed as a relative value on a scale of 0 to 100, it is necessary to convert energy savings to a comparable value for both comparison and development of a single effectiveness value. Placing BTU savings on a scale of 0 to 100 implicitly sets energy savings achieved equal to impacts. If, however, BTU savings were placed on a scale of 0 to 10, impacts would be 10 times more important than energy savings when the measures are compared and ranked. In this study, both impact and energy savings were placed on a scale of 0 to 100, i.e., treated equally. Energy savings are converted to relative values between 0 to 100 in the same manner described for impacts under Step 1.

STEP 3 - Single Evaluation and Ranking Value

The final ranking is based upon the addition of the relative impact value and the relative energy saving value. The measure with the highest score is ranked first and the measure with the lowest score is ranked last.

This methodology was applied twice. First, based upon the cumulative savings and impacts associated with the measures between 1977 and 1990, and second, based upon the 1990 savings and impacts alone. The former ranking takes into account the staging of energy savings and impacts (i.e., short term versus long term). The latter ranking considers the measure only at full development. Hence, in the cumulative 1977-1990 ranking, measures with large savings potential, which could not be implementated until 1985 or later, would be penalized in terms of cumulative savings. Conversely, an immediate action measure with a lower level of annual savings displays higher effectiveness. The ranking, based upon 1990 savings, considers each measure at its maximum potential within the study time frame.

The results of the application are described in Appendix H.

F. FINDINGS AND CONCLUSIONS

As indicated earlier, the primary objectives of the effort were to develop a replicable evaluation methodology to review, evaluate and rank energy conservation measures and to test the methodology on a selected set of measures. The results of the study indicate that these objectives have been achieved.

1. Methodology

As a result of the test application presented in Appendix H of the report, it was found that the methodology provided both the workability and utility for evaluation and ranking of energy conservation measures by federal, state and local governments. During the test application, the methodology proved to be sound, flexible and simple to execute.

The soundness of the methodology was demonstrated by the general consistency of results when subjected to a limited qualitative review. The relative ranking level of each specific measure was found responsive to and consistent with the policy objectives implicit in the methodology or explicitly introduced into the methodology by EPA staff (e.g., impact importance weights.)

Of equal importance, the methodology was found to be flexible in that alternative policy objectives can easily be introduced into the methodology and the conservation measures reranked. This will be particularly important under different methodology applications, such as implementation strategy testing, state and local government use, and national policy or program development.

The methodology, as developed, is dependent upon two major data requirements: (1) quantified achievable energy savings; and (2) quantified impact estimates. The quality of the evaluation and ranking results are directly dependent upon the quality of data.

Based upon the test application, it was found that in many instances, the required data was of poor quality, nonexistent or difficult to relate to a specific energy conservation measure. This was particularly true for quality of life data, environmental data and various implementation strategy elements, such as public acceptability.

For this reason, the test application results must be considered in light of data constraints. While there is no question that improved data would provide much better results, obtaining improved data and developing better estimates require investment of both time and money. This requirement could serve to limit or constrain methodology use by state and local governments.

2. Energy Savings

The results of the analysis of energy savings are presented in Figures I-2 and I-6 for the residential, industrial, commercial, transportation and power generation sectors.

The potential for energy savings is severely restricted in many cases by the implementation mechanism and/or other major nontechnological constraints. These bounds are defined by the differences between technologically feasible savings and estimated achievable savings.

Since the level of achievable savings--in most cases--is highly dependent upon the implementation strategy used, there appears to be a case for concentrated development, testing and refinement of possible implementation strategies. However, it was also observed, that for certain measures, achievable savings are almost entirely independent of implementation strategies, e.g., industry production capability. In these cases, implementation must be focused on removal of constraints, rather than use of incentives, disincentives, mandates and legislation.

Figure I-7 lists the major constraints to achieving the maximum technologically feasible savings and shows the estimated achievable savings as a percent of the maximum technologically feasible savings.

FIGURE I-2

SUMMARY OF ENERGY SAVINGS - RESIDENTIAL SECTOR

(Trillion BTU's)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Space Heating Efficiency	113	295	463	681	94	245	384	523
Residential Insulation	653	914	1333	1739	104	157	242	325
Appliance Efficiency	865	1348	2221	2863	865	1348	2221	2863
Thermostat Control	895	967	1077	1195	537	583	647	717
Solar Energy/Heat Pumps	12	56	256	683	12	56	256	683

FIGURE I-3

SUMMARY OF ENERGY SAVINGS - INDUSTRIAL SECTOR

(Trillions of BTU's)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Direct Heat and Steam Raising*	2736	2896	3194	4437				
Energy Intensive Processes*	973	1060	1265	1491				
Recycling	255	293	354	428	3	15	97	214
Packaging	568	753	1047	1289	0	0	0	1289
Non-returnables	307	354	448	568	0	0	448	568
Total Energy Systems	383	418	505	592	4	21	26	148
Natural Fertilizers	65	71	75	82	42	46	48	53

*These measures were not evaluated by Peat, Marwick, Mitchell & Co. and therefore no estimates of achievable savings are presented.

FIGURE I-4

SUMMARY OF ENERGY SAVINGS - COMMERCIAL SECTOR

(Trillions of BTUs)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Ventilation	1153	1313	1617	1921	0	661	1434	1647
Air Flow	124	141	174	206	0	66	164	191
Temperature Control	1000	1139	1403	1667	586	703	770	885
Task Lighting	193	219	270	321	0	133	159	192
Total Energy Systems	7.5	17.2	35.9	54.5	.08	1.5	6.2	12.7
Solar Energy/Heat Pumps	105	288	717	1094	0	17	43	109

FIGURE I-5

SUMMARY OF ENERGY SAVINGS - TRANSPORTATION SECTOR

(Trillion BTU's)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Increased Car Pooling	2,448	2,586	2,904	3,408	840	885	975	1,167
Increased Auto Efficiency	1,175	1,895	2,830	3,464	0	1,690	2,790	3,464
Increased TOFC Use	239	255	282	297	2.4	5.1	11.3	17.8
Intercity Modal Shifts	121	248	414	575	121	248	414	575
Increased Bus Transit	2,618	2,739	3,000	3,480	25	60	138	263
Improved Airplane Scheduling & Load Factors	250	662	1,286	2,208	NE	NE	NE	NE
Reduced Highway Speed Limits	928	1,057	1,312	1,623	NE	NE	NE	NE

Note: NE indicates achievable energy savings not estimated.

FIGURE I-6

SUMMARY OF ENERGY SAVINGS - POWER GENERATION SECTOR

(Trillions of BTUs)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Direct Firing of Solid Waste	54	97	447	759	54	97	447	759
Pyrolysis of Solid Waste	0	3	25	80	0	3	24	80
Bioconversion of Solid Waste	0	3	18	58	0	3	18	58
Waste Heat Recovery	0	1431	4496	7451	0	1431	4496	7451
Wind Energy	0	1	31	137	0	1	31	137

FIGURE I-7

IMPLEMENTATION CONSTRAINTS TO ACHIEVING ENERGY SAVINGS

Conservation Measure	Primary Achievability Constraint	Estimated % Achievable[1]
Residential Sector		
1. Space heat	Retrofit voluntary response level	83.0
2. Insulation	Retrofit voluntary response level	17.9
3. Appliance efficiency	Regulation - All or nothing	100.0
4. Thermostat control	Voluntary response level	60.0
5. Solar	Develop time/market penetration	100.0[2]
Commercial Sector		
1. Reduced ventilation	Regulation implement time lag	72.3
2. Reduced air flow	Regulation implement time lag	73.4
3. Task lighting	Regulation implement time lag	84.4
4. Thermostats	Voluntary response level	60.0
5. Total energy system	Market penetration	22.4
6. Solar	Market Penetration	5.2
Transportation Sector		
1. Intercity mode shift	Equipment constraint/market penetration/consumer economics	4.3
2. Urban shift to bus	Equipment constraint	100.0[2]
3. Carpooling	Pub. resistance/alter. transit options	34.6
4. COFC/TOFC	Equipment constraint	3.6
5. Auto efficiency	Voluntary tune up-response level/ economics	92.3
Industrial Sector		
1. Natural Fertilizer	Availability/market penetration	65.0
2. Packaging	Legislation time lag	25.2
3. Total Energy System	Market penetration	12.8
4. Recycling	Legislative implement time lag	19.6
5. Returnable bottles	Legislative implement time lag	52.0
Power Sector		
1. Direct firing	Development time/economics	100.0[2]
2. Pyrolysis	Development time/economics	100.0[2]
3. Bioconversion	Development time/economics	100.0[2]
4. Waste heat recovery	Plant siting/develop. time/economics	100.0[2]
5. Wind energy	Research & development time/economics	100.0[2]

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[1] Percent of maximum technologically feasible savings.

[2] Based on the Peat, Marwick and Mitchell assumption that the primary constraint in these measures is technological, the achievable savings are equal to the maximum technologically feasible savings.

3. Impacts

The impact evaluation is presented in two ways. First, the energy savings and the impacts associated with each conservation measure are arrayed to permit a convenient accounting of the magnitude of various impacts and to allow their possible rearrangement and/or reassessment to suit the priorities of the individual examining the data. Second, the impacts are presented in their normalized and weighted form to demonstrate the application of the methodology.

Figures I-8 and I-9 provide the accounting of impacts by presenting the estimated feasible energy savings and the estimated impacts associated with each conservation measure on a 1977 - 1990 cumulative basis, and for 1990, respectively. The cumulative impacts provide a perspective on energy conservation over time. The 1990 impacts provide a perspective on energy conservation following full implementation.

A series of assumptions were made to facilitate the development of impact values for test purposes. For future applications, the impact data can be developed under alternative sets of assumptions, depending on evaluation requirements. Following are the major assumptions and simplification procedures used:

- each measure was assumed to be independent of each other measure;
- energy prices were assumed to be constant (1974);
- dollar estimates are constant 1974 dollars;
- only direct impacts were considered;
- no adjustments were made where impacts could not be estimated;
- in some cases surrogate rather than direct values were used to estimate impacts;
- future oil import dependancy was assumed to average 18% between 1977 and 1990; and
- 1974 environmental control technology was assumed.

FIGURE I-8

CUMULATIVE IMPACTS
(1977-1990)

	Energy Savings (BTU's x 10^{12})			Public Sector (Millions of $)				
	Feasible	Private Industry (Mil. of $)	Private Consumer (Mil. of $	Government (Mil. of $)	Balance of Payments (Mil. of $)	Employment (Jobs) 1/	Environ. % Poll. Reduction)	Quality Of Life Assigned Impact (0-10)
RESIDENTIAL								
1. Space heating	4,237	11,605	4,660	0	519	0	0.042 SO_2	0
2. Insulation	3,023	20,317	607	(871)	370	0	0.092 SO_2	0
3. Appliances	23,288	0	148,323	0	3,984	0	2.700 SO_2	-1
4. Thermostat control	8,786	0	25,512	(1.4)	266	0	0.110 SO_2	-1
5. Solar heat	3,577	25,798	1,929	(733)	74.4	0	.084 SO_2	0
COMMERCIAL								
1. Ventilation	14,154	61,592	0	0	4,338	0	0.250 SO_2	-2
2. Air flow	1,591	8,152	0	0	510	0	0.029 SO_2	-2
3. Task lighting	1,978	10,371	0	0	634	0	0.029 SO_2	0
4. Thermostat setting	10,489	50,400	0	(1.4)	3,363	0	0.150 SO_2	-1
5. Total Energy	832	3,620	0	0	86	0	0.04 SO_2	0
6. Solar assisted heat pumps	484	2,590	0	0	153	0	0.016 SO_2	0
INDUSTRIAL								
1. Fertilizer	670	(4,500)	4,500	0	215	(11,789)	0.060 SO_2	0
2. Packaging	2,293	(7,900)	7,900	(395)	735	(62,691)	9.500 SW	-3
3. Total energy systems	851	2,128	0	0	278	0	.230 SO_2	0
4. Recycling	1,093	1,418	0	(4,680)	350	(187,207)	4.000 SW	0
5. Nonreturnables	3,048	3,600	12,700	899	977	0	7.400 SW	-1
TRANSPORTATION								
1. Intercity passenger mode shift	1,769	49,750	(12,968)	(8,842)	533	39,000	0.179 CO	0
2. Increased carpooling	13,696	0	88,664	(11,038)	4,383	0	1.000 CO	-1
3. Shift to bus	5,025	40,547	8,379	(14,163)	1,607	34,900	.380 CO	0
4. Auto efficiency	31,089	0	125,788	(25,146)	9,948	0	0 CO	0
5. TCFC/COFC	135	3,706	0	0	43	9,300	0.900 CO	0
POWER								
1. Direct firing	4,602	8,405	1,681	0	0	0	30.00 SW	0
2. Pyrolysis	340	(610)	(122)	(46)	1.9	0	1.300 SW	0
3. Bioconversion	247	27	5	0	1.9	0	1.340 SW	0
4. Wind energy	501	(801)	(160)	0	45	0	.280 SO_2	0
5. Waste heat recovery	47,547	29,848	0	0	1,317	0	8.200 SO_2	0

1/ Zero denotes areas for which employment estimates were not possible. Does not denote zero impact. Utility and energy supplier employment not included.

FIGURE I-9

ANNUAL IMPACTS
1990

	Energy Savings (BTUs x 10^{12})	Annual Impacts - 1990						
				Public Sector (Millions of $)				Quality of Life
	Feasible	Private Industry (Mil. of $)	Private Consumer (Mil. of $)	Government (Mil. of $)	Balance of Payments (Mil. of $)	Employ.1/ (Jobs)	Environ. (% Poll. Reduction)	Assigned Impact (0-10)
RESIDENTIAL								
1. Space Heating	523	1078	531	0	69	0	0.042 SO_2	0
2. Insulation	325	1451	68	(62)	40	0	0.092 SO_2	0
3. Appliances	2863	0	16748	0	490	0	2.700 SO_2	-1
4. Thermostat Control	717	0	2073	(0.1)	22	0	0.110 SO_2	-1
5. Solar Heat	683	4336	254	(109)	14	0	0.084 SO_2	0
COMMERCIAL								
1. Ventilation	1647	7197	0	0	528	0	0.250 SO_2	-2
2. Air Flow	191	835	0	0	61	0	0.029 SO_2	-2
3. Task Lighting	192	1125	0	0	61	0	0.029 SO_2	0
4. Thermostat Setting	885	4254	0	(0.1)	283	0	0.150 SO_2	-1
5. Total Energy	.82	670	0	0	16.7	0	0.04 SO_2	0
6. Solar Assisted Heat Pumps	109	478	0	0	39	0	0.016 SO_2	0
INDUSTRIAL								
1. Fertilizer	53	(364)	364	0	17	(11879)	0.060 SO_2	0
2. Packaging	917	(2638)	2638	(132)	299	(62691)	9.500 SW	-3
3. Total Energy Systems	148	351	0	0	47	0	0.230 SO_2	0
4. Recycling	214	278	0	(916)	69	(187207)	4.000 SW	0
5. Non-Returnables	568	671	2357	168	182	0	7.400 SW	-1
TRANSPORTATION								
1. Inter-City Passenger Mode Shift	263	7697	(4240)	(761)	85	39000	0.179 CO	0
2. Increased Car Pooling	1167	0	8015	(934)	373	0	1.000 CO	-1
3. Shift to Bus	575	4334	958	(1622)	184	349000	.38 CO	0
4. Auto Efficiency	3464	0	13993	(2799)	1107	0	0 CO	0
5. TOFC/COFC	18	476	0	0	6	9300	0.900 CO	0
POWER								
1. Direct Firing	759	1276	255	0	0	0	30.000 SW	0
2. Pyrolysis	80	(143)	(29)	(31)	0.45	0	1.300 SW	0
3. Bioconversion	58	6	1.3	0	0.32	0	1.340 SW	0
4. Wind Energy	137	(218)	(44)	0	12.00	0	0.280 SO_2	0
5. Waste Heat Recovery	7,451	5029	0	0	206.0	0	8.200 SO_2	0

1/ Zero denotes areas for which employment estimates were not possible. Does not denote zero impact. Utility and energy supplier employment not included.

4. Evaluation and Ranking Test Results

A test of the evaluation and ranking methodology was accomplished through use of the methodology described in Section E. The methodology required that all impacts be treated as positive. Thus, the most severe negative impact was tabulated as a zero in the normalized impacts. A less severe impact was assigned a higher normalized value.

Figure I-10 presents the overall energy conservation measure evaluation and ranking results based upon cumulative 1977-1990 energy savings and impacts. Waste heat recovery, improved appliance efficiency and improved auto efficiency rank first, second and third respectively, both in terms of feasible energy savings, and when impacts and energy savings are considered simultaneously. The energy savings associated with these measures, when combined, would be over 100,000 x 10^{12} BTU's between 1977 and 1990.

If the top ranked energy conservation measures in each sector were implemented, almost 120,000 x 10^{12} BTU's could be conserved between 1977 and 1990. This estimate represents a maximum achievable level of energy savings at a minimum negative impact to both private and public sectors.

Figure I-11 presents the results of the evaluation and ranking of the energy conservation measures based only on energy savings and impacts estimated for the year 1990. This alternative ranking minimizes development time constraints in the evaluation, since each measure is considered at its most advanced stage of development.

Figure I-12 compares the energy conservation measure ranking based on cumulative 1977-1990 results with the rankings obtained using annual 1990 results. As shown in Figure I-12, waste heat recovery, auto efficiency and applicance efficiency are the three top measures in both cases. Carpooling, which ranks sixth in the cumulative analysis, drops to eighth in the 1990 ranking, since

FIGURE I-10

ENERGY CONSERVATION MEASURE EVALUATION AND RANKING BASED UPON 1977-1990 CUMULATIVE ENERGY SAVINGS AND IMPACTS

MEASURE	ENERGY SAVINGS BTUs x 10^{12}	SAVINGS SCORE	IMPACT SCORE	SAVINGS AND IMPACT SCORE	RANK
Waste heat	47,547	100.0	54.1	154.1	1
Appliances	23,288	48.6	55.6	104.2	2
Auto efficiency	31,089	64.9	27.4	92.3	3
Ventilation	14,154	29.4	45.8	75.2	4
Recycling	1,093	2.0	69.8	71.8	5
Carpooling	13,696	28.4	42.1	70.5	6
Commercial thermostat	10,489	21.7	45.4	67.1	7
Urban shift to bus	5,025	10.3	52.9	63.2	8
Direct firing	4,602	9.4	51.3	60.7	9
Intercity mode shift	1,769	3.4	52.2	55.6	10
Residential thermostat	8,786	18.1	35.2	53.3	11
Bioconversion	247	0.2	52.0	52.4	12
Pyrolysis	340	0.4	51.8	52.2	13
TOFC/COFC	135	0.0	50.8	50.8	14
Returnables	3,048	6.1	44.4	50.5	15
Space heat	4,237	8.6	37.9	46.5	16
insulation	3,023	6.1	40.1	46.2	17
Fertilizer	670	1.1	45.0	46.1	18
Task lighting	1,978	3.9	40.6	44.5	19
Residential Solar	3,577	7.2	36.7	43.9	20
Wind	501	0.8	40.1	40.9	21
Industrial TES	851	1.5	39.2	40.7	22
Packaging	2,293	4.5	34.1	38.6	23
Commercial TES	832	1.7	36.3	38.0	24
Commercial solar	484	0.7	35.9	36.6	25
Air flow	1,591	3.1	29.2	32.3	26

FIGURE I-11

ENERGY CONSERVATION MEASURE EVALUATION AND RANKING BASED UPON 1990 ENERGY SAVINGS AND IMPACTS

MEASURE	ENERGY SAVINGS BTUs x 10^{12}	SAVINGS SCORE	IMPACT SCORE	SAVINGS AND IMPACT SCORE	RANK
Waste heat recovery	7,451	100.0	58.0	158.0	1
Appliances	2,863	38.3	61.3	99.6	2
Auto efficiency	3,464	46.4	39.4	85.8	3
ventilation	1,647	21.9	46.6	68.5	4
Direct firing	759	10.0	54.2	64.2	5
Recycling	214	2.6	59.9	62.5	6
Urban shift to bus	575	7.5	53.9	61.4	7
Carpooling	1,167	15.5	43.7	59.2	8
Intercity mode shift	263	3.3	55.4	58.7	9
Returnables	568	7.4	49.6	57.0	10
Commercial thermostat	885	11.7	44.0	55.7	11
Pyrolysis	80	0.8	54.5	55.3	12
Bioconversion	58	0.1	54.9	55.0	13
TOFC/COFC	18	0	53.5	53.5	14
Residential solar	683	8.9	41.3	50.2	15
Packaging	917	12.1	37.3	49.4	16
Fertilizer	53	0.4	48.0	48.4	17
Space heat	523	6.8	40.1	46.9	18
Residential thermostat	717	9.4	37.3	46.7	19
Insulation	325	4.1	41.5	45.6	20
Task lighting	192	2.3	42.5	44.8	21
Wind	137	1.6	42.7	44.3	22
Industrial TES	148	1.7	42.0	43.7	23
Commercial TES	182	1.5	39.0	40.5	24
Commercial solar	109	1.2	38.9	40.1	25
Air flow	191	2.3	31.7	34.0	26

FIGURE I-12

CUMULATIVE 1977-1990 RANKING VERSUS ANNUAL 1990 RANKING

MEASURE	1977-1990 CUMULATIVE RANK	1990 RANK
Waste heat recovery	1	1
Appliance recovery	2	2
Auto efficiency	3	3
Reduce ventilation	4	4
Recycling	5	6
Carpooling	6	8
Commercial thermostat	7	11
Urban shift to bus	8	7
Direct firing	9	5
Intercity mode shift	10	9
Residential thermostat	11	19
Bioconversion	12	13
Pyrolysis	13	12
TOFC/COFC	14	14
Returnables	15	10
Space heat	16	18
Insulation	17	20
Fertilizer	18	17
Task lighting	19	21
Residential solar	20	~~16~~ 15
Wind energy	21	22
Industrial TES	22	23
Packaging	23	16
Commercial TES	24	24
Commercial solar	25	25
Reduced air flow	26	26

carpooling is an immediate-action program and over time represents a diminishing proportion of energy conservation.

Conversely, reduced packaging, a long-range measure, shifts from twenty-third under the cumulative ranking to sixteenth under the 1990 ranking. This occurs primarily because of delayed implementation, i.e., post-1985.

5. Potential Application of the Methodology

Once the basic energy saving estimates and impact estimates were made, the methodology was found to be both efficient and easy to use in application. In addition, the basic simplicity and transparency of the methodology suggests that the methodology can be used effectively by the policy maker, as well as the technician.

Based upon the test application and the results of that application, the methodology appears to be suited for or adaptable to the following types of uses:

- evaluation of a large number of measures to assist in policy and/or program development;
- identification of promising policy approaches and conservation measures for additional development and/or research;
- evaluation of alternative policy programs and/or specific implementation strategies;
- development of hierarchical conservation programs to assist in resource allocation; and
- identification and focusing of future energy conservation research needs.

II. ENERGY CONSERVATION IN THE RESIDENTIAL SECTOR

A. INTRODUCTION

Residential demand for energy has increased greatly in recent years and can be expected to continue its rapid growth into the future. There are a number of measures which, if adopted, could considerably reduce this rate of growth. As described in Chapter I, five measures have been selected in this study for analysis of their practical potential for energy conservation. These measures are listed below and summarized in Figure II-1:

1. Increased efficiency of space heating.
2. Increased use of residential insulation.
3. Minimum efficiency standards on major appliances.
4. Thermostat setting to conserve energy.
5. Use of solar energy and/or heat pumps in residential buildings.

Figure II-2 summarizes residential use of energy. It shows that the largest proportion of residential energy is used for space heating and water heating. Cooking, air conditioning and refrigeration are other major uses of domestic energy. For each of these uses of energy there are significant potentials for energy conservation which have been examined in this report. The fifth measure, the use of solar energy and heat pumps, refers to the use of combination systems as well as the use of each type of unit individually.

The literature sources relevant to residential energy conservation as well as the statistics available for analysis are incomplete, fragmented, and were developed for diverse purposes. A relatively few studies form the basis for most of the data used by analytical expositions on the subject. In many cases, both the basic sources and the analyses utilizing their data tend to concentrate on special cases rather than overall survey information. This method is used because the high cost of detailed field analyses makes the cost of statistically significant repetition of experiments prohibitive. Thus, it is often necessary to generalize the data

Figure II-1

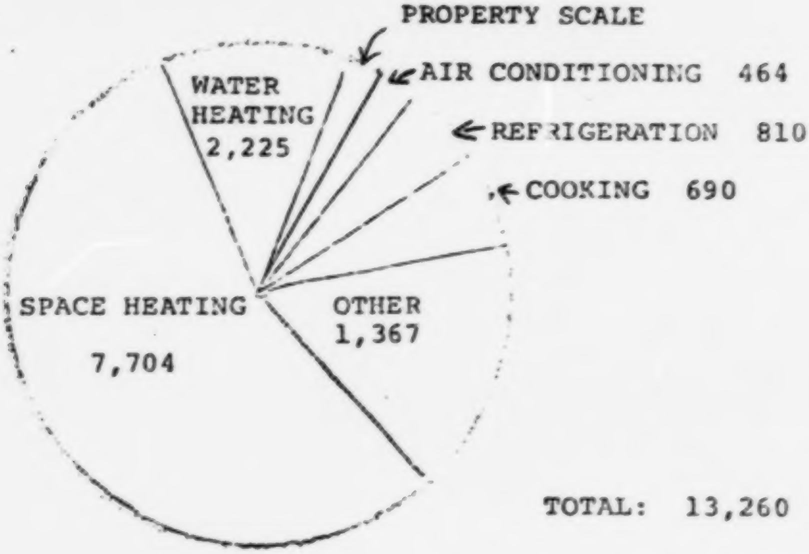
ENERGY CONSERVATION MEASURES IN THE RESIDENTIAL SECTOR

Serial No.	Conservation Measure	Implementation Strategy
R-1	Increasing the efficiency of residential space heating	Mandatory factory installation of flue heat recovery devices on all new furnaces (under FTC or FEA regulation) and annual cleaning and maintenance of these furnaces (prompted through means such as public appeal and education).
R-2	Increasing use of residential insulation and increasing storm window and door retrofitting	a) Upgrading FHA/VA minimum standard for insulation in new housing construction, b) Providing federal and/or state income tax benefits for costs incurred in retrofitting insulation and storm windows and doors in existing dwellings.
R-3	Implementing minimum efficiency ratings and standards on new major appliances	Establishing federal standards under FEA or FTC regulation.
R-4	Changing thermostat settings	Voluntary means such as public appeal and education.
R-5	Use of solar energy and/or heat pumps for heating and cooling	Allowing a tax credit for accredited solar energy/heat pump systems.

FIGURE II-2

RESIDENTIAL ENERGY CONSUMPTION BY USE-1970

(including electric generation heat loss)
in trillion BTUs



SOURCE: MATHEMATICA Energy Data Base, as estimated from data on saturation and per unit energy usage from Patterns of Energy Consumption, (SRI, 1972) and the 1970 Census of Housing (Census, 1970).

Figure II-3

SUMMARY OF ENERGY SAVINGS - RESIDENTIAL SECTOR

(Trillion BTU's)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Space Heating Efficiency	113	295	463	681	94	245	384	523
Residential Insulation	653	914	1333	1739	104	157	242	325
Appliance Efficiency	865	1348	2221	2863	865	1348	2221	2863
Thermostat Control	895	967	1077	1195	537	583	647	717
Solar Energy/Heat Pumps	12	56	256	683	12	56	256	683

from the special cases in order to assume a good "ballpark" estimate of a national average. An example would be the use of a "characteristic" house for a study of the effects of different amounts of insulation. While this house may be representative of houses in general as based upon a preliminary survey, to use it to determine a national average represents an entirely different concept. However, due to the lack of information on the widely varied mix of residential housing, insulation, design, age, use and location, this technique is used.

B. SUMMARY OF APPROACH AND RESULTS

There are three steps to the approach used to calculate the energy savings potential of each measure. First, a national average percentage energy savings per physical consumption unit; i.e., refrigerator, occupied house, air conditioner, was estimated. Second, base case national forecasts of aggregate energy consumption were made through 1990 for each of the types of physical units affected by the energy conservation measure. Finally, total national energy savings potential was calculated by applying the national average percentage energy savings to the appropriate forecasts of energy consumption.

Once estimates of maximum energy savings potential were made, these were scaled down to yield the achievable energy savings due to each measure. This scaling down is done on the basis of an evaluation of various feasibility constraints which limit the effectiveness of measures and may be somewhat judgemental in nature. Examples of constraints would be lack of public acceptance, practical limitations on the number of physical units to which a measure is applicable, and expected delays in the production of energy saving devices or materials.

The impacts of energy conservation measures are estimated separately on the basis of the expected achievable energy savings. These account for such factors as changes in product price and sales volumes, life style, and air pollution.

Appendix J details more thoroughly the approach taken to estimate energy savings potential while Appendix E explains the methodology used for deriving achievable energy savings and impacts.

Figure II-3 summarizes the maximum and achievable energy savings which could result from the proposed measures.

C. INCREASED EFFICIENCY OF SPACE HEATING

1. Maximum Energy Savings

The largest segment of residential energy consumption is used for space heating. In 1970, space heating represented 11% of U.S. total energy consumption.[1] According to the 1970 Census of Housing, 92.3% of occupied housing units use fossil fuels for space heating. The remaining 7.7% primarily uses electricity. The heating systems used in fossil fuel heated housing units are often inefficient due to intermittent operation and deposits of soot on heat transfer surfaces.

It should be noted that the efficiency rating of furnaces is a matter of some dispute. Thermal efficiency is defined as the ratio of the number of BTUs of heat introduced into the home to the BTUs released by the fuel. Furnace manufacturers generally claim 75% to 85% efficiency. This efficiency is the theoretical efficiency of the furnace under ideal conditions. However, some HVAC engineers claim that the true thermal efficiency of fossil fuel heating systems is between 40% and 60%. For gas furnaces, the American Gas Association[2] has a rating system and will not approve furnaces that are not at least 75% thermally efficient.

A recent article[3] seems to clarify the nature of the difficulty. In the past, heating system efficiency has been measured in tests in homes. In this environment, there are other heat sources; cooking equipment, other appliances, people at 98.6F, solar heating effects, etc. Often the household heat gain from these sources is factored into the calculation of heating system efficiency, obviously resulting in too high an estimate for system thermal efficiency. Thus, the lower estimate of between 40% and 60% is probably more correct.

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[1] MATHEMATICA estimate based on Patterns of Energy Consumption, (SRI, 1972) and the 1970 Census of Housing.

[2] AGA, 1971.

[3] Dunning, 1974

The efficiency of the furnace units under ideal conditions is termed the "peak efficiency" while the "seasonal efficiency" of furnaces is the efficiency delivered over a period of time under actual operating conditions. According to Berg[1], intermittent operation of furnaces in practice tends to allow the accumulation of soot on boiler and other heat transfer surfaces which tends to decrease the efficiency of the furnaces. Regular furnace maintenance should increase this efficiency by 10% according to the National Bureau of Standards[2], but this estimate is unsubstantiated by factual data. Conversations with HVAC engineers reveal that in order to realize this amount of savings, the furnace to be cleaned would have to be extremely dirty. A more reasonable estimate would be in the range of 5%, but this estimate is also speculative. There simply is no hard data in this area. Actually, while some soot will be accumulated during on-off cycles as the air to fuel mix changes, the major detrimental effect of intermittent operation is the drawing of warm inside air into the flue where it is lost. This effect may be quite large in some furnaces.

The largest cause of furnace inefficiency is waste heat. The energy is lost both as flue gas at elevated temperatures and as heat transferred prematurely in ductwork. A number of methods for reducing this waste are now available. Among these are flue gas recovery, damper systems, and insulated ductwork.

Flue gas is normally heated to the 450° to 560° range as it leaves the furnace. This is the maximum temperature allowed by the A.G.A.[2] standards. Reducing the temperature of this flue gas can result in up to 13% fuel savings[3]. The amount of fuel actually saved

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1. Berg, 1973.
2. NBS, 1973.
3. Hittman, 1974.

depends upon efficiency of the recovery unit and the manner in which the furnaces operate. There are two currently available technologies which would allo [illegible] fuel savings. These are recuperative heat exchangers wi[illegible] the furnace and "high performance furnace designs" which are gas-liquid heat exchangers. There are minor problems associated with these systems, such as the need for forced ventilation of the cooled flue gas and the corrosive action of condensates from oil furnaces. The first problem can be solved easily, and the second lends itself to solution because the cooler flue gas allows the use of more corrosion-resistant materials.

Damper systems are used to shut off flues during off period cycles. Hittman[1] estimates that the use of these devices could save 10% of fuel needs in a furnace. There are, however, dangers from trapped fumes and for this reason they are banned by many local building codes. Damper systems are, therefore, not considered as practical energy conservation devices.

In many heating systems, there are heat losses in the ductwork that conveys warm air through the building. These losses occur when the ducts pass through the cold areas such as attics and crawl spaces, and can be reduced by insulating the ductwork in these areas. There is currently no significant data relative to the impact of this effect in housing units on an aggregate basis. Thus, although improvements are possible in this area, they will not be considered in calculations of improved furnace efficiency in this report.

An alternative method of space heating is to combine the space and water heating systems into a single system which combines the functions of both. A number of such systems have been developed, a successful system being that described by Piper[1]. This system uses a controlled closed loop of circulating water at 140°F. as a source of both hot water and energy for space heating. The company claims that their system uses much less energy for both water and space heating than do conventional space heating units. Further claims include decreased initial and operating costs, the ready adaptibility of solar energy, high reliability for both space and water heating, reduced fire hazard, and applicability to all types of residential buildings. Currently, there are no independent evaluations of the Piper system, but given the large savings claimed, this system merits further study.

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[1] Hittman, 1973.

In summary, the estimates of energy savings from increasing the efficiency of space heating considered only the savings from flue heat recovery and regular maintenance. The combined conservation potential from these measures is estimated to be an average savings of 15% of the energy consumption for each fossil fuel burning unit.

The maximum energy savings potential from the adoption of these measures is estimated to be 113, 275, 463 and 631 trillion BTU in 1977, 1980, 1985 and 1990, respectively , as illustrated in Figure II-4.

Appendix B describes the means of aggregating unit savings to derive the maximum savings potential. In this appendix, it is assumed that the potential savings is realizable only in fossil fuel furnaces in new construction.

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[1] Piper, J. R. "Series Systems Utilizing Domestic Hot Water for Space Heating", ASHRAE Journal, reproduced in Appendix D of this report.

Figure II-4

MAXIMUM ENERGY SAVINGS POTENTIAL
INCREASED EFFICIENCY OF SPACE HEATING

	1977	1980	1985	1990
Baseline Consumption (trillion BTU's)	753	1833	3087	4207
Units (millions)	71.1	74.6	80.8	74.6
Percent Savings Per Unit	15%	15%	15%	15%
Total Savings (trillion BTU's)	113	275	463	631

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

The two implementation strategies chosen to increase efficiency of home space heating were the installation of flue heat recovery devices on new home furnaces and the annual cleaning and maintenance of those new furnaces. Heat recovery devices save twice as much energy as the cleaning and maintenance step; therefore, since all new furnaces would be required to have these devices, a simplifying assumption was made that 66 2/3 percent of the estimated potential energy savings (the proportion associated only with flue heat recovery devices) would be ensured.

The total technologically feasible energy savings associated with annual maintenance and cleaning are based upon the net difference between energy consumed by new and replacement homes assuming no annual cleaning and maintenance and energy consumed by new and replacement homes assuming 100 percent annual cleaning and maintenance. However, a report for the Office of Emergency Preparedness[21] indicated that currently only one half of the people with furnaces have them cleaned and maintained annually. If it is assumed that one half of new home owners would also perform annual cleaning and maintenance in any event, then only one half the maximum technologically feasible energy savings associated with annual cleaning and maintenance can be considered as potential energy savings.

Since no quantified data was available, it was assumed that only the expected one half of new home owners would perform annual cleaning and maintenance. This assumption implies that there would be no true new net energy savings associated with annual cleaning and maintenance.

For purposes of the study, the energy savings associated with 50 percent of new home owners who are expected to perform annual maintenance and cleaning are considered as avoidance of possible energy consumption. These energy savings are included in the feasible energy savings estimates shown in Figure II.

Using the above flue heat recovery device assumptions and the annual cleaning and maintenance assumptions, achievable energy savings are estimated at 83 percent of maximum savings or 4237×10^{12} BTU's between 1977 and 1990. However, there are other nonquantified factors important in considering implementation of this measure.

- In order to implement the first step of the measure, the factory installation of heat recovery devices, it would be necessary to enact national legislation to require these devices. It might be difficult and time consuming for such legislation to pass, although there are some related legal precedents, noted a recently passed California law. This law, according to an FPC spokesman, provides for a state commission to prescribe minimum standards of efficiency for all appliances including furnaces. Other possible precedents include a New York City ordinance and the requirements for installation of automobile pollution control devices under the Clean Air Act of 1970.
- Information was not available on existing Federal agencies which might be responsible for administering a similar residential measure; however, it would not seem difficult for the FTC or another agency. Regarding the public education step for furnace cleaning and maintenance, the Federal Power Commission already has a campaign underway to help utility

companies educate their customers to have their furnaces cleaned and maintained, and thus save money on heating bills. The possibility therefore exists that in the future more than one-half of owners of both new and older furnaces will have them cleaned and maintained.

- In the area of enforceability, the heat recovery devices on furnaces would seem to present no problem, since all new furnaces would come equipped. However, since the cleaning and maintenance of the furnaces would be voluntary on the part of the customer, there could be no enforcement.
- An FPC spokesman indicated that there probably would be some resistance on the part of consumers to buying furnace maintenance contracts, since the homeowner cannot always see immediate savings in his fuel bills. In addition, it is probable that furnace manufacturers would be adverse to the implementation of a measure such as this which required heat recovery devices, since it would add considerably to the price of their furnaces. Figure II-5 summarizes the impacts.

IMPACTS

Private Consumer

Private consumers will realize a direct operating savings from reduced fuel consumption. Assuming constant average home heating costs of $166/year or $1.44/MMBUT, each dwelling unit affected would save approximately $25 per year in operating costs. Based upon the average projected changes in consumption of energy per unit and the estimated savings, aggregate consumer savings would be approximately $6.6 billion between 1977 and 1990.

It was not possible to estimate added cost associated with installation of improved heat recovery systems. For purposes of the analysis $100 is the assumed capital cost for heat recovery devices, manpower and installation. The annual cost at 10% per year over 15 years would be $13/year. Annual maintenance cost could run between $25 and $50. Using the midpoint of $37.50, the annual maintenance cost would be approximately $2.00/MMBTU saved. While annual maintenance cost results in energy savings, the process results in a net cost to the consumer. Since it was assumed that only 16.7 percent of energy saved can be attributed to annual maintenance, the estimated maintenance cost is estimated at $1532 million between 1977 and 1990. Annualized capital cost for flue heat recovery are estimated at $414 million between 1977 and 1990. Between 1977 and 1990 the consumer will realize a $4660 million net savings in home heating costs.

Public Sector

The public sector costs associated with this measure would be related to the administrative expenses of federal agencies responsible for enforcing the minimum applicance efficiencies. Primarily involved would be the Federal Trade Commission and the National Bureau of Standards. FTC's incremental expenses would be minimal because that agency is already involved in enforcement of other consumer product standards.

Most of the public sector burden of the program would have to be absorbed by NBS which would be responsible for testing each model furnace of each manufacturer for energy efficiency. (No such energy efficiency testing for appliances is currently done on a national basis.) Some manpower and materials expenses could be encountered in this operation.

Figure II-5

SPACE HEATING IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	113	295	463	631	5,105
2. Estimated Feasible	94	245	384	523	4,237
B. Impacts (Millions of Dollars)					
1. Private Industry					
Furnace Industry	$245m	$633m	$1,070m	$1,078m	$11,605m
2. Private Consumer					
Savings	$134m	$328m	$553m	$753m	$6,606m
Maintenance Cost	($31.4m)	($76.2m)	($128m)	$175m)	($1,532.2m)
Annualized Capital Cost	($8.5m)	($20.6m)	($34.6m)	($47.2m)	($414.1m)
Net Savings	$94m	$231m	$390m	$531m	$4660m
3. Public Sector					
Government	Insufficient Data				
Balance of Payments	$11.4m	$27.9m	$47.0m	$69.0m	$519m
4. Employment (Jobs)					
Furnace Industry*					
Furnace Maintenance Industry*					
5. Environment (Percent Reduction)					
SO_2 Reduction	.018%	.034%	.051%	.042%	

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*Increased employment could be expected in these sectors but data was not available to allow quantitative estimation.

Between 1977 and 1990, it is estimated that approximately $519 million in energy imports would be avoided.

Scarce Materials and Resource

There is no critical resources or materials problem associated with this measure.

Quality of Life

Of the factors considered in the quality of life criteria--comfort, mobility, recreation, schedule change--all but comfort are unaffected by this measure. While comfort should be improved somewhat through increasing of space heat efficiency (due to more uniform heat levels), there are few substantive data to document the degree of this comfort improvement.

Environment

The sulfur dioxide (SO_2) reduction effect of the space heating measure is extremely small in relation to total SO_2 emissions--only on the order of one percent relative to SO_2 emissions from overall residential energy.

The rather small effect is due, in large part, to the fact that relatively pollution-free natural gas accounts for a large portion of energy supply related to space heating.[1] Natural gas is projected to increase in use in home heating. Electrically heated homes are also expected to increase to about 6.5 percent by 1990 (American Gas Associated Projections).

Private Industry

As shown in the space heating impact summary table, the furnace industry will realize approximately $11.6 billion in added revenues between 1977 and 1990 as a result of the more complex and expensive heating units required by this measure.

There will be a direct impact on furnace installation and maintenance cost as a function of modification of units. There are presently insufficient data to estimate the added costs/revenues associated with furnace systems modifications in the areas of installation and maintenance.

Employment

Fuel suppliers could suffer some loss in employment growth between 1977 and 1990 while manufacturing of new furnace components could stimulate some employment incrementals. It has been assumed that installation and modification can be accomplished without significant employment changes. Additional furnace cleaning and maintenance men might also be required to service the furnaces as the practice of cleaning contracts grows.

D. INCREASED USE OF RESIDENTIAL INSULATION

1. Maximum Energy Savings

Insulation is a means of increasing the efficiency of both space heating and space cooling. Many different types of insulation can be installed in homes. Fiber or foam insulation of ceiling, walls or floors, storm doors, storm windows, double pane glass, reflective glass, weather stripping, and caulking can all be used. The most effective mix of methods varies with use (heating or cooling), type of fuel, and climatic conditions.

Current Federal regulations in this area are limited to the FHA Minimum Property Standards (MPS) for one and two unit housing[1] and multi-unit housing.[2] The FHA-MPS requirements consist of a maximum allowable overall heat transfer coefficient for a residential building, among requirements in other areas. These standards are required only if a residence is to qualify for a FHA mortgage. As such, they apply only to a small percentage of residential construction. Even these requirements are minimal in nature, requiring only standards which "assure present continuing utility, durability and desirability as well as compliance with basic safety and health requirements".[3] The Minimum Property Standards, moreover, do not take into account regional variations in climate. Thus, in some regions, the MPS standards are too low for minimum insulation needs, while in others they are too high. It should be noted that a new set of MPS is expected to be released by the FHA within several months and these should take into account regional variations.

In addition to the Federal standards, there are other standards to which some builders must comply. Many of these standards, for example, that of the Electric Energy Association of New York[4] are more stringent than MPS. As a result, some homes, particularly electrically heated homes, actually are insulated beyond MPS standards.

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[1] FHA, 1973a

[2] FHA, 1973b

[3] Ibid.

[4] (EEA-NY, 1972)

Many builders and homeowners have had, until recent increases in the price of fuel, little incentive to utilize home insulation at or above MPS levels. Builders are in an economic position where they must try to minimize first costs. Similarly, home and apartment owners often do not plan to own their housing units long enough for the full financial benefits of additional insulation to be realized through decreased energy expenditures. Furthermore, the typical homeowner just does not have the information on the amount of money insulation could save. Multiple unit dwellings are especially difficult because the owner is often not responsible for the fuel bills. The result of these conditions is a housing stock which is extremely wasteful of thermal energy. It has even been estimated[1] that half the one and two unit homes in the U.S. have no insulation at all.

Improvements in the insulation of the U.S. housing stock can be both retrofit on existing units and placed in new construction. The amount and type of insulation most feasible for each of these two categories is different and varies within each category by type of building and climate. The following discussion will develop data for making per unit estimates of energy savings for both the retrofit and new construction markets.

Results are generalized for a typical house. Because of the lack of statistical data on housing insulation characteristics, it takes "typical" estimates as an average and then sums the aggregate savings on a nationwide basis. There may be problems because of the wide variation in housing characteristics in considering the "typical" house as an "average" house in the statistical sense. It may introduce considerable bias into the estimate. Not only is this a numerical bias in describing the

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[1] Haufler, 1973.

the anticipated aggregate effect of insulation; many effects in housing units may be totally different in kind from that projected on the "typical" unit. Housing units are extremely complex thermodynamic systems. Almost everything that occurs in and around the unit affects the temperature balance within. Heat may be transferred in or out through conduction convection, radiation, or the latent heat of moisture. Thus, the type and magnitude of the effect of a measure on a building is extremely building-specific.

A discussion of the effect of increased insulation for existing and new homes follows:

1. Retrofit Insulation

The basic difficulty with retrofitting insulation into existing homes is simply that they are already built and functioning. Home improvement may not be one of the higher priorities for the individual homeowner. More importantly, many areas such as walls, floors, and ceilings may be blocked off, thus making the installation of insulation difficult. Wall and floor insulation is expensive to put in existing buildings because it requires the services of a professional specialist who, in most cases, must drill holes in walls and floors to blow insulation material (usually urethane foam)into cavities. This method cannot be used at all with masonry construction.

There are, however, three practical and relatively simple insulation methods which can be readily adopted to the existing stock of one and two unit dwellings. These methods are attic insulation, storm windows and sealing openings through weather stripping. Information supplied by the FEA[1] indicates that there are 18 million homes, mostly over 25 years old, with accessible attics and 3 or less inches of attic insulation. These homes can be prime targets of a program to install insulation. Additionally, many one and two unit dwellings can be fitted with storm windows and doors. FEA also estimated that about half the one and two unit dwellings could be fit with them.[1] Again, there is no hard data, but this report uses 20 million units as as estimate of storm windows and doors. This is just under half the total number of one and two unit dwellings in the country. It is assumed that up to 20 million homes which do not currently use weatherstripping can be fitted.

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[1] Personal communication with Daniel Quigley, Office of Energy Conservation, Federal Energy Administration.

Thermopane windows have roughly the same thermal characteristics as storm windows and may be used instead. They have two advantages over storm windows. First, they are kept on all year, thus helping to cool the house in the summer when air conditioning is turned on. Second, they can easily be opened in the summer as an alternative to air conditioning.

The 18 million homes with less than 3 inches of attic insulation and accessible attics had an average area of 1120 square feet. This was used as a basis of calculation of heat loss and gain for heating and cooling, respectively.

This FEA information is based on a survey by an insulation manufacturer. Contact with the manufacturer revealed that the survey was based on a sample of 300 houses in each of 18 cities. The manufacturer further indicated that, of these 18 million homes, about 44% had 0-2 inches of ceiling insulation and about 56% had 2-3 inches. They had an average area of 1120 square feet. The area of these homes is smaller than the current national average because these are older homes. Currently this is the best information publically available. Until recently, there has been little interest in this question and comprehensive statistics have not been gathered. Information is available on the amount of insulation sold annually, but it is not possible to determine the distribution of use by geography, type of building or whether it is used in new or existing building stock. It is possible to state that the use of insulation has increased greatly in recent years. Two studies are currently being carried out for which information should be available in late 1974. Both measure the amounts of insulation in the existing housing stock. One, by the Washington Center for Metropolitan Studies contains insulation information as part of its analysis for the Ford Foundation Energy Project Policy. The other, by the National Association of Home Builders, is specifically addressed to the problem of insulation in existing buildings.

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[1] Ibid.

The 0 - 2 inch insulation was assumed to be an average of the equivalent of R-3[1] and the 2 - 3 inch insulation was assumed to represent R-7 installation. The shingles, roof and ceiling and attic space were assumed to add R-4 in insulation value. An average annual heating degree day of 5000 was assumed.[2] This climate would be slightly warmer than New York City. For the 0 to 2 inch insulation, the total value would be R-7 and for the 2 to 3 inch insulation the total value would be R-11. Current MPS standards would call for a minimum value of R-13. Calculations assuming a fossil fuel furnace of 50% service efficiency based on the NAHB insulation manual[3] show a 7.9% decrease in heating energy requirements and a 10.3% decrease in cooling energy requirements.

Hittman[4] examined the effects of storm windows in their characteristic house study for HUD. They were able to show a 9.4% heating energy savings and a 23.4% cooling energy savings. These savings include a 50% reduction in losses through infiltration. The house under study was a particularly "loose" house with a high proportion of energy lost through infiltration. For this reason, the estimated savings are believed to be somewhat high for what is "average" in the U. S. For heating, a Princeton[1] study found heating fuel differentials of 5 - 10.5% in identical units which could be attributed to thermopane windows. These findings, however, apply to townhouses and split level homes. Based upon evaluation of these two sources, MATHEMATICA estimates that the "average" energy savings for storm or thermopane windows is about 6.5% for heating and 12% for cooling.

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[1] The "R" value is defined as the reciprocal of the thermal conductivity of a material. It is a measure of the thermal resistance of the material. Thus, higher "R" values imply greater insulating capability

[2] A "degree day" is a measure of the amount of heating energy used. For each day, the average temperature is below 65°F., the average temperature is subtracted from 65°F. This is the degree day contribution for that day. The annual degree day is the sum of the daily contributions.

[3] NAHB, 1971

[4] Hittman, 1973

Air infiltration is the primary source of heat losses in houses. It can be caused by both structural defects and open doors, windows and other vents. According to the Hittman[2] report, 55.2% of the heating load and 41.5% of the cooling load in a typical house is due to infiltration. Using sealant, caulking and weatherstripping is another means of reducing infiltration. The amount of savings to be realized varies, of course, with the condition of the dwelling. Assuming that about one tenth of the heating load is eliminated by these measures, a 5% saving results. Three per cent of the cooling load is assumed to be eliminated, resulting in a 1.2% savings of energy. These assumptions are based solely on judgement because no hard survey data exists.

Figure II-6 shows the projected potential energy savings from retrofitted insulation. These potential savings are derived by applying the unit percent energy savings developed in this section to the energy consumed by the affected housing units as shown in appendix B.

Figure II- 6

POTENTIAL MAXIMUM ENERGY SAVINGS FROM RETROFIT INSULATION[1]

Type of Insulation	Percent Unit Savings	Applicable Units	Savings (10^{12} BTU)			
			1977	1980	1985	1990
Attic Insulation						
heating	7.9	18 million existing	184	179	170	162
cooling	10.3	1 & 2 unit homes	18	17	16	16
Storm or Thermopane Windows						
heating	6.5	20 million existing	170	165	156	148
cooling	12.0	1 & 2 unit homes	23	22	21	20
Weatherstripping						
heating	5.0	20 million existing	131	127	120	114
cooling	1.2	1 & 2 unit homes	2	2	2	2
Total Savings			528	512	485	462

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[1] for explanation, see text and appendix B.

2. New Construction

New residential construction can be fitted with an adequate amount of thermal insulation from the start. This includes insulation of ceilings, walls and floors as well as storm windows and doors or thermopane glass windows. Two studies recently estimated national average per unit reduction in energy consumption with the use of thermal insulation. One, by the National Mineral Wool Association[1], calculated the increased efficiency of changing typical housing units to MPS standards with current average energy consumption. The other, by Moyers[2], calculated the energy savings per unit in going from current MPS levels to an optimum level of insulation in single unit dwellings. This optimum level of insulation was the amount of insulation that yielded maximum economic benefit to the homeowners with the 1970-71 fuel prices. Another article by Hirst and Moyers[3], summarized these results in more useful form

The Moyers' reports deal exclusively with single family housing while the National Mineral Wool Association report concerns itself with all types of dwellings. Estimates for energy improvement per unit will be on a basis of MPS standards as calculated by the Mineral Wool Report.

The increased insulation would be potentially applicable to all one, two and multi-unit dwellings. Heating savings would total 33% for all types of dwellings. Cooling energy savings would be 8.0% for one and two unit homes and 11.0% for multi-unit dwellings.

This results in an underestimation of possible energy savings as additional insulation is possible beyond MPS standards. On the other hand, there is an overestimation of the amount of savings possible by increasing to MPS standards because construction standards have already improved since the Mineral Wool Association Report (1971). It was felt necessary to limit the increase of insulation to a specific level rather than an elusive and changing economic optimum. Forecasts of potential energy savings follow the methodology of appendix B and are summarized below in figure II-7.

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[1] Mineral Wool, 1971

[2] Moyers, 1971.

[3] Hirst and Moyers, 1973.

Figure II-7

SUMMARY OF SAVINGS FROM INCREASED INSULATION IN NEW CONSTRUCTION[1]

UNIT TYPE	% UNIT SAVINGS	APPLICABLE UNITS	SAVINGS (10^{12}BTU)			
			1977	1980	1985	1990
1 and 2 units						
heating	33	All new construction	86	277	578	858
cooling	8	"	3	11	24	37
Multi-units						
heating	33	"	33	107	231	361
cooling	11	"	3	7	15	21
Total			125	402	848	1277

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[1] See text and appendix B for details.

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

As stated earlier, the new construction section of this measure applies to all one, two and multi-unit dwellings, while the retrofit construction applies to one and two-unit dwellings.

In arriving at feasible energy saving estimate for this measure, it was assumed: (1) that only 20 percent of new housing "starts" are built to FHA/VA specifications[1] (whether or not they are eventually sold under FHA/VA financing); and 2) that only a range of 10-20 percent of current home-owners would take advantage of a tax incentive to retrofit their houses with better insulation.

The latter range was based upon an estimate of 10 percent given by a utility company spokesman whose company had succeeded in getting 4 percent of their customers to retrofit insulation under a special financing plan and an intensive public relations and education program. However, this estimate was believed to be conservative, so a 10-20 percent rate was created. Feasible energy savings are estimated as 20 percent of potential new construction energy savings plus 15 percent (mid point of the 10-20 range) on the estimates of retrofit in existing homes. Between 1977 and 1990, the estimated cumulative feasible savings would be approximately 3023 x 10^{12} BTU's or an average of 18 percent of total possible BTU savings.

In addition, several insulation industry reports, including a report for the Department of Commerce,[2] indicated that the capacity of the insulation industry would have to be doubled in order for the expected needs to be met, and that it would take several years for the industry to reach "full steam." In lieu of definitive data the feasible energy savings between the years 1977 and 1980 were arbitrarily reduced by 50 percent to compensate for build-up time for production of insulation.

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[1] HUD, 1973

[2] Energy Savings in Existing Dwellings, background paper for Dept. of Commerce, 1973

There were several other major considerations which would impact the implementation feasibility of this measure.

- In the area of necessary legislative action, this measure would require income tax incentives for retrofitting insulation (for this analysis were assumed at the 50 percent level). For new construction, the recently revised FHA minimum property standards (just released in the fall of 1974) mandate a correlation between the amount of total insulation and the summer and winter climatic extremes (in terms of degree days) of different areas of the country. This correlation may have the effect of increasing insulation beyond current regional levels. In addition to comfort and safety, the MPS now mention conservation of energy as a factor in residential insulation.
- Senate Bill 2176, which is currently being considered by the U.S. Senate, contains provisions for developing model building codes to include strong standards for energy efficiency and to incorporate those standards into the FHA-MPS. However, according to an aide on the Senate Interior Committee, this bill has only a 50 percent chance of passage in its present form. In addition, there currently are no precedents for personal tax benefits to individuals for "environmental" home improvements (though there are precedents for other types of home improvements). For these reasons, this measure would probably not be difficult to implement.

- There would also be some negative attitudinal factors involved with the home insulation measure. Builders of new homes would be adverse to increasing the initial cost of houses to give them the new insulation. Also, as stated earlier, it was estimated that only about 15 percent of those owning older homes would be inclined to take advantage of a tax incentive to retrofit the recommended insulation.

IMPACTS

Figure II-8 summarizes the impacts.

Private Consumer Cost/Earnings

The use of increased housing insulation would benefit two consumer groups: those retrofitting current homes and those purchasing new homes. The impact analysis for each is presented separately, since different rates of dollar cost and/or savings will accrue to each.

Retrofits

It is assumed all retrofits will be accomplished at a constant annual rate through 1990. The total per unit savings in heating and cooling expenditures, as a result of insulating attics, installing storm doors and windows and weatherstripping to meet FHA's 1974 Revision 2 to Minimum Property Standards is estimated at 20 percent. This would lower the average $212[1] yearly heating and cooling expenditures per household by approximately $42.

Annual operating savings must be offset by the capital expenditures associated with increased insulation. The Department of Commerce estimates these costs to be as follows:

1. Insulation	$225.00
2. Storm Doors & Windows	$420.00
3. Weatherstripping	negligible
	$645.00[2]

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[1] [illegible] Action Guide to Energy Conservation, op. cit.

[2] Commerce, op. cit.

FIGURE II-8

INSULATION IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	653	914	1,333	1,739	16,843
2. Estimated Feasible	104	157	242	325	3,023
B. Impacts (Millions of Dollars)					
1. Private Industry					
Insulation Added Annual Revenue	$1,451m	$1,451m	$1,451m	$1,451m	$20,317m
2. Private Consumer					
Savings	$132m	$530m	$1,148.5m	$1,802m	$13,532m
Annualized Capital Cost	($127m)	($510.6m)	($1,105.5m)	($1,733.7m)	($12,952m)
Net Savings	$5m	$ 20m	$43m	$68m	$607m
3. Public Sector					
Government	($62m)	($62m)	($62m)	($62m)	($871m)
Balance of Payments	$12	$17m	$27m	$36m	$332m
4. Employment (Jobs)					
Insulation Industry		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	.060%	.074%	.087%	.092%	

Since the implementation strategy for this measure assumes a 50 percent state or federal income tax credit program, the actual capital cost to the consumer would be $322.50. If the cost is assumed to be added to the homeowner's current mortgage at an average interest rate of 8 percent and the average 30 year mortgage is assumed to be 15 years old, the annual capital cost is estimated at $38. Thus, the annual operating savings are offset by $38, leaving $4 as the net savings to the consumer.

Assuming 15 percent of the 18 million homes requiring added insulation would in fact add insulation, the estimated 1990 annual consumer savings would be $10.8 million.

New Construction

The total per unit savings in heating and cooling expenditures, as a result of meeting the new FHA minimum property standards in new one and two and multi-unit housing is estimated at 28 percent. This would lower the average $212 yearly heating and cooling expenditures per household by approximately $59.

Annual operating savings must be offset by the capital expenditures associated with the increased insulation (which the builder would have added to the purchase price of the house).

If the builder passed on the entire $645, which will be assumed to be the cost of insulating a new home as well as an old one, the consumer's mortgage would be increased by this increment. Using the formula for total annual installment payments, and computing on the basis of a 30-year mortgage, the annual cost would be $57. Thus, the annual operating savings are offset by $57 and the new annual savings to a purchaser of a new home would be $2.

The cumulative impact to consumers between 1977 and 1990 for both retrofit and new housing would be $607 million net savings.

Public Sector

The public sector costs associated with this measure would be the lost federal tax revenues as a result of the tax credits for retrofits. This is estimated as the $332.50 tax credit per unit times 18 million units times the 15 percent realization factor, or $871 million for the 1977-1990 period. Between 1977 and 1990, it is estimated that approximately $332 million in energy imports will be avoided.

Scarce Resource/Materials

There are no critical resources or material problems associated with this measure.

Quality of Life

Comfort should increase through implementation of this measure--due to reduction of drafts and heat loss. However, there are no quantified data on the degree of comfort increase that the measure will effect.

Environment

Projected reductions in SO_2 emissions (in lbs. x 10^6) through implementation of this measure are expressed in a range as follows:

	1977	1980	1985	1990
Upper Level	20.6	69.1	118.1	143.7
Lower Level	15.5	51.9	87.9	128.2

The widespread use of clean natural gas minimizes the direct environmental benefits of this energy oonservation measure. Nevertheless, in the period from 1977 to 1990, there would be a decrease in SO_2 emissions from approximately .06 percent to .09 percent of SC_2 emissions.

Private Industry

According to the Department of Commerce, the mineral wool industry would be most impacted by a program to insulate old and new homes. Aluminum and glass industries would also be impacted because they produce the materials for the manufacture of storm windows and doors. No detailed data were available for the aluminum and glass industries.

Based upon Department of Commerce estimates, the total cost of upgrading insulation in the average home is estimated at $645.00 for insulation, storm windows and doors. Assuming that both retrofit insulation demand and new home construction added insulation demand is distributed equally during the period from 1977 to 1990, annual added revenues would be approximately $1.5 billion per year. The cumulative added revenues for the insulation industries between 1977 and 1990 would total over $20 billion in sales and installation services.

Employment

The Department of Commerce anticipates that increased production of mineral wool, glass and aluminum can be met without large relative increases in total industry capacity. The one "industry" that will be greatly affected, however, is the home installers of the insulation. The impact on employment as a result of added demand, cannot be determined because employment data for "home insulation installers" could not be found. (The closest employment estimate would be for SIC 1521, General Contractors; however, several general contractors who were contacted reported they did a negligible amount of home insulation, particularly retrofitting).

However, estimated demand, combined with the general knowledge that installing attic insulation and storm doors and windows is highly labor intensive, suggests that employment in the industry will be positively stimulated as a direct result of this measure.

E. IMPLEMENT MINIMUM EFFICIENCY STANDARDS ON MAJOR APPLIANCES

1. Maximum Energy Savings

Because of the large and increasing share of residential energy consumption they represent, it is important to use major appliances efficiently. Four major appliances, hot water heaters,air conditioners, and refrigerators/freezers and stoves and ovens are responsible for 30.0% of residential energy demand.[1] This is broken down as follows:

Air Conditioners	3.7%
Hot Water Heaters	14.9%
Refrigerators/Freezers	5.9%
Stoves and Ovens	5.5%

The total amount of energy used by these appliances is increasing for several reasons. First, the appliance units are becoming larger. Second, the market saturation of some of these appliances, notably the air conditioner and clothes dryer has increased dramatically in recent years. There are no indications that the trend towards increasing market saturation will be reversed. Third, technological changes are leading to increased energy consumption. For instance, increasing numbers of frost-free refrigerators and freezers are being used. These consume significantly greater energy than the conventional appliances. For each of the appliances listed above, significant energy savings are possible. These energy savings measures are outlined in the following discussion.

Air Conditioners

Space cooling is the fastest growing segment of residential energy consumption. This energy consumption is almost entirely electrical and in 1970 represented 3.7%[2] of residential energy consumption. Of wired households, 27% had room air conditioners and 11% had central air conditioning.[3] Until recently, few consumers paid attention to air conditioner efficiency. Air conditioners were purchased mainly with consideration given to price and size and often on an impulse basis. Thus, there was no incentive to manufacturers to increase the efficiency of air conditioners.

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[1] SRI, 1972

[2] MATHEMATICA estimate based on SRI data and 1970 appliance saturation data

[3] Merchandising Week, February 23, 1974

The efficiency of an air conditioner is measured in terms of the ratio of BTUs of heat removed from the environment to watt hours of electricity delivered. The Association of Home Appliance Manufacturers (AHAM) has a rating program for air conditioner efficiency. Air conditioners of participating manufacturers are rated in terms of cooling capacity and efficiency. This rating system involves a series of spot tests conducted by the Electrical Testing Laboratories, Inc, which validates cooling capacity and efficiency. These ratings, once approved by AHAM are listed on the nameplates of the air conditioner. The Air Conditioning and Refrigeration Institute (ARI) maintains a certification program under which over 90% of air conditioning units are sold. For the manufacturers the ARI certification represents a more important control than the AHAM rating program. Under the ARI certification program, anyone can challenge a rating placed on an air conditioner. The ARI will then go into the manufacturer's factory, pick out random units, and test them. If just one type of air conditioner does not meet the certification rating, the manufacturer losses certification on his entire line of air conditioners.

A recent study by Oak Ridge National Laboratory[1] of different types of room air conditioners found a large range of rated cooling capacities and efficiencies for room air conditioners presently on the market. The results of this study are shown in Figure II-8. Clearly, for each rated cooling capacity there are air conditioners

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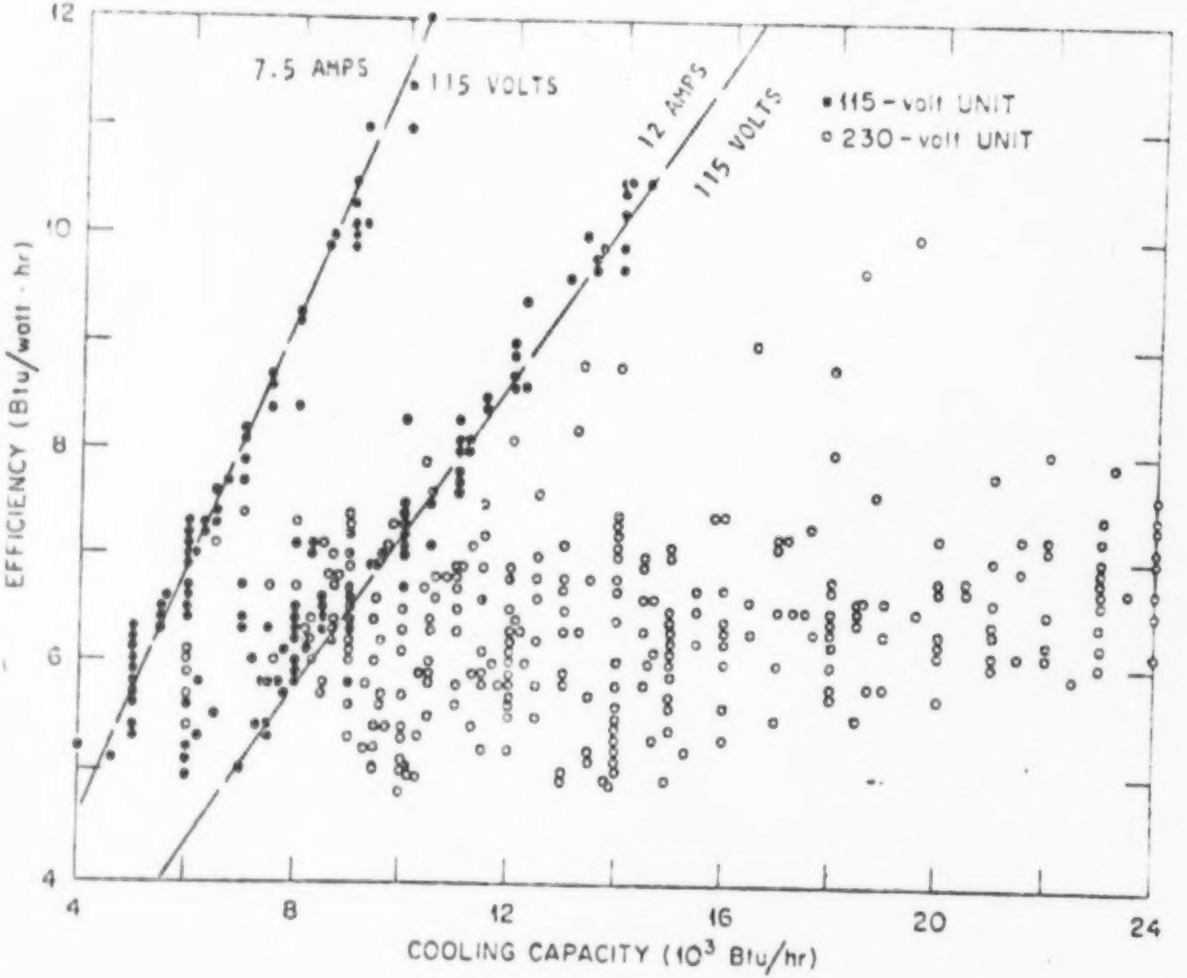
[1] Moyers, 1971

FIGURE II-8



Efficiency of Room Air Conditioners.

Source: Moyers, John, The Room Air Conditioner as an Energy Consumer, ORNL-NSF-EP-59, October 1973.

with many different efficiencies. Most air conditioners operate on either 115 volts or 230 volts, so that they can be used with ordinary household circuits and comply with applicable national electric code requirements. The average efficiency of room air conditioners is now about 6 BTU/watt-hrs. Efficiencies up to 12 BTU/watt-hrs. are commercially available. An increase in the average efficiency from 6 to 10 BTU/watt-hr. would decrease average electrical consumption per unit by 40% of the average current consumption. It should be noted that the current accepted value for average air conditioner efficiency, 6 BTUs/watt-hr., is based upon the Oak Ridge National Laboratory Study. Since this study does not present information on the relative market shares of each of the units studied, the assumption is that none of the different units represent a very large percentage of the air conditioning market.

A study by Booz Allen Applied Research[1] for the Experimental Technology Incentives Program for the National Bureau of Standards evaluates the difficulties, technical and otherwise, of implementing a program of increasing the efficiency of air conditioners. These difficulties result from the increased size, noise, and cost of air conditioners. All three represent problems to the air conditioning industry because they run counter to the criteria consumers usually apply in purchasing air conditioning. Increasing the efficiency of air conditioners can be accomplished by increasing the size of heat transfer surfaces, using water instead of air for condensing the refrigerant, and redesigning the air flow. These modifications not only tend to make the unit larger, but also noisier from increased vibrations,and more expensive. While it appears that increased size may be a necessary price to pay for increased efficiency, the noise level can be reduced by various design measures such as insulation of the compressor and the insertion of sound-absorbing materials, but they will make the air conditioning unit still larger and more expensive.

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[1] Booz Allen, 1973a.

For air conditioning units already in use, regular cleaning can result in increased operating efficiency of the machine. Decreases in efficiency over time are attributable to the accumulation of various types of dirt on the evaporator and condenser coils. This dirt restricts the heat transfer necessary for efficient operation. NBS[1] estimates that regular cleaning of the air conditioner system can reduce energy consumption by 10 percent. This estimate appears to be based upon engineering judgement, rather than actual data. In some cases allowing system parts to be cleaned may require redesigning of the system so as to allow easy access of the surfaces to be cleaned. The easiest method of cleaning the air conditioner is simply to regularly replace the air filter.

Central air conditioning units have an average energy efficiency ratio (EER) of between 8 and 9.[2] Increasing this ratio to an average of 10 would produce about a 15% energy savings per unit. This percentage savings will be used in forecast calculations of total savings from central air conditioning units.

The fact that central air conditioning units have higher energy efficiency ratios does not imply that the average consumption per dwelling unit is lower for central than room air conditioning units. In multi-unit buildings, in order to cool one or a few units, the entire central unit must be turned on. If room air conditioners are used, which individually may have lower efficiencies than the central unit, the total amount of energy consumed may actually be less because of the smaller amount of total equipment that is being operated.

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[1] NBS, 1973

[2] Conservation Foundation, 1973

The aggregate national potential energy savings from air conditioner improvements and maintenance is calculated in appendix F.1. In that appendix, it is seen that the expected savings in trillion BTU are as follows:

	1977	1980	1985	1990
Clean all units	36	42	53	62
Improve efficiency of room units	33	76	127	154
Improve efficiency of central units	13	37	75	107
	82	155	255	323

It should be noted that the "cleaning" potential is applied only to new units and thus may underestimate the actual potential. The calculations were performed on this basis to keep them consistent with the other parts of this measure.

Hot Water Heaters

In 1970 energy consumption for residential hot water heating represented 15% of residential energy consumed and 2.9% of total U.S. energy consumption.[1] Water heaters are of two types: standard and quick recovery. Because quick recovery water heaters allow for an unlimited supply of hot water, they consume greater amounts of energy than do standard types of the same capacity. During the last 20 years, average energy requirements and capacity of hot water heaters has increased dramatically from 2500 watts and 30 gallon capacity to 4500 watts and 52 gallon capacity. Since the 1960s, quick recovery units have been the predominant type sold.[2] This increase in power consumption and capacity is due to rising affluence and the growth in the use of dishwashers and clothes washing machines.

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[1] MATHEMATICA estimate based upon SRI, 1972 and 1970 appliance saturation data.

[2] Vars 1, 1973

Hot water heaters consist basically of an insulated tank and a heating element. Fossil fuel units have a flue through the middle of the tank for the escape of combustion gases. Electric hot water heaters usually have two inches of fiberglass or mineral wool insulation and tend to be somewhat larger than fossil fuel units. Fossil fuel units typically have only one inch of insulation and a 35% average annual heat loss. Most hot water heaters have an adjustable thermostat with a range of settings between 100°F and 160°F.

A comprehensive study by J. Mutch of the Rand Corporation[1] considered four methods of energy conservation for hot water heating: increased tank insulation, pipe insulation, temperature lowering, and on-off cycles for periods of low use. Mutch concluded that pipe insulation and on-off cycles produced only minimal energy savings and were not cost justified. In some larger buildings, however, there may be large heat losses through water pipes, in which case insulation of these pipes may be warranted. Large energy savings were shown for increased insulation and temperature reduction. Both these measures could be retrofit or placed in new units.

Figure II-9, from the Mutch study, shows the relationship between input energy use and insulation thickness. Two strategies of insulating would be:

1. Insulate to minimize lifetime costs
2. Insulate to total cost equal to prior total life time cost, but with energy savings; i.e., higher capital costs and lower operating costs)

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[1] Mutch, 1974

Mutch has provided a very detailed discussion of these strategies in his work.

Most hot water heaters maintain water temperatures between 140°F. and 150°F. The range of typical hot water usages, however, is only about 100 to 120°F.[1] It should be noted that only two uses, automatic dishwashers and clothes washers, require the use of water at the temperatures delivered. Some of these machines, have their own heating units which maintain the water used at this temperature, but many do not.

The amount of energy required to offset heat losses is directly proportional to the difference between water temperature and ambient air temperature. Therefore, reductions in energy expenditure can result from reducing this difference by lowering water temperature. The relative amount of energy reduction depends upon the amount of insulation used. As insulation is increased, the amount of heat transferred decreases, thus diminishing the energy savings from temperature reduction. These relationships are shown in Figure II-10. If ambient air temperature is at 70°F., electric water heaters will consume 3% less energy per 10°F. reduction in water temperature and fossil fuel units will consume 5% less per 10°F. reduction in temperature with standard insulation. With six inch insulation, just under 2% of energy is saved by both kinds of units per 10°F. fuel reduction.

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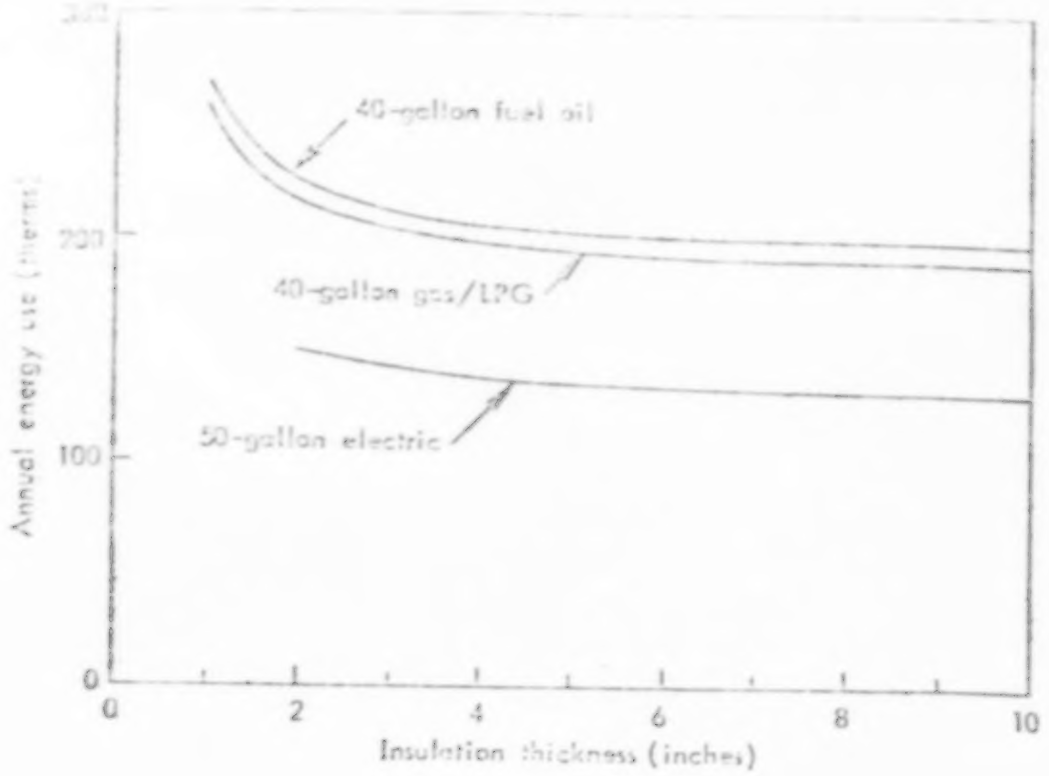
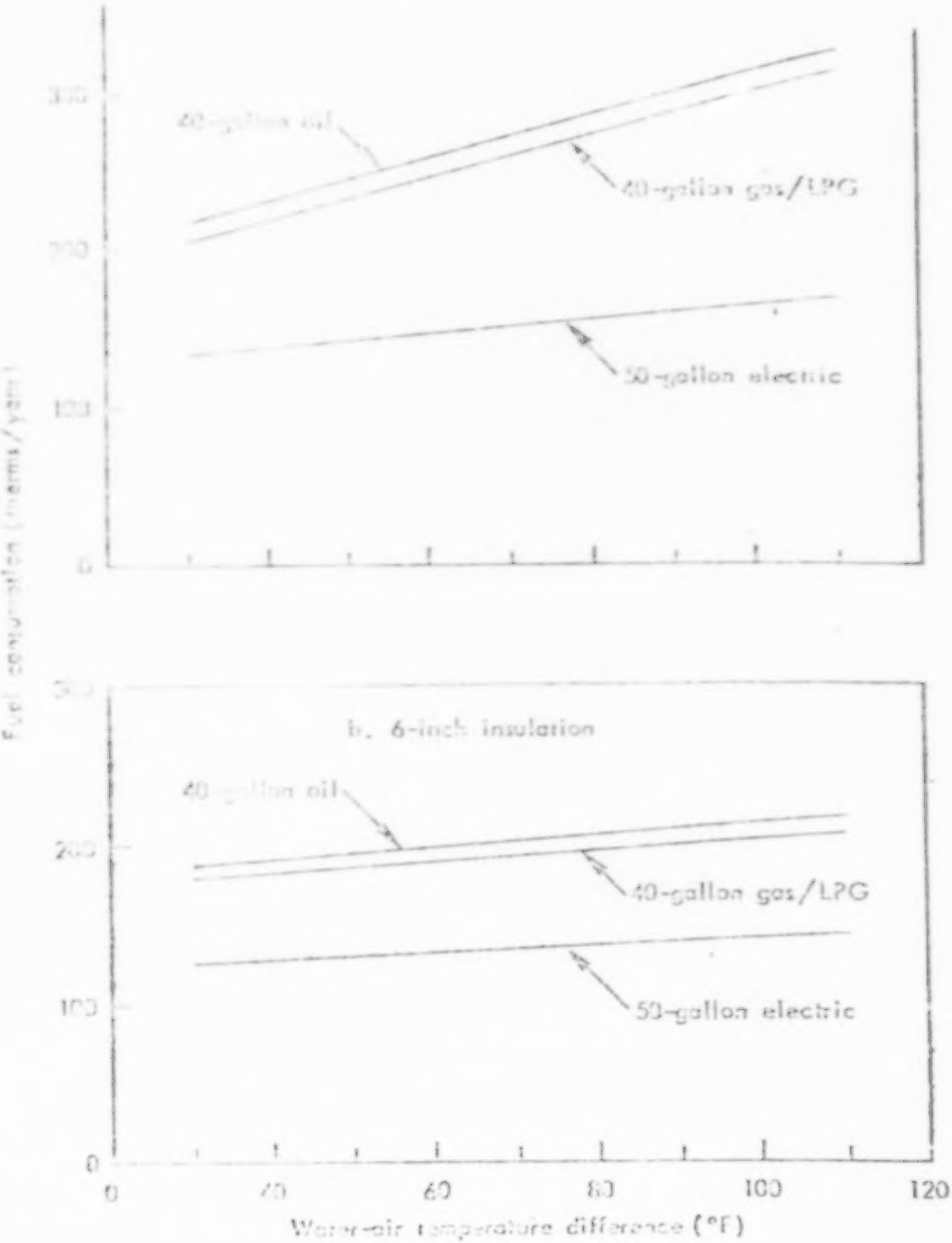
[1] Hittman, 1972.

FIGURE II-9



Annual energy use of residential water heaters as a function of tank insulation thickness

Source: Mutch, J. J., Residential Water Heating Fuel Conservation, Economics and Public Policy, RAND Corporation, R-1498-NSF, May 1974.



Effect of hot water temperature on annual energy consumption for several types of residential water heaters

Source: Mutch, J. J., Residential Water Heating Fuel Conservation, Economics and Public Policy, RAND Corporation, R-1498-NSF, May 1974.

Figure II-11contains information on per unit energy savings for each of Mutch's insulation strategies. MATHEMATICA will assume that the minimum cost option will be used because the economic savings to the consumer are viewed as a necessary incentive for implementation. Both increased insulation and reduced water temperatures are used. The average per unit energy savings then becomes 25%, based upon a weighted average of the different types of hot water heaters. Forecast maximum savings from this measure, as developed in Appendix   in this report, reach 617 trillion BTU in 1990.

Figure II-11

COST MINIMIZATION OPTION *

Energy Savings Percent

FUEL	Savings Due to Insulation	Savings Due to 20°F Temperature Reduction	Total Savings
Electric	11.0	4.0	14.6
Natural Gas/ LPG	23.8	3.5	26.5
Fuel Oil	23.8	3.5	26.5

EQUAL COST OPTION

Energy Savings Percent

FUEL	Savings Due to Insulation	Savings Due to 20°F Temperature Reduction	Total Savings
Electric	11.8	3.5	14.9
Natural Gas/ LPG	27.0	3.0	29.2
Fuel Oil	27.0	3.0	29.2

*Used as basis of calculations of energy savings potential

Refrigerators/Freezers

Refrigerators and freezers accounted for 16% of residential electricity use in 1970 and 6.5% of total U.S. energy use.[1] Refrigerators have already saturated the home market, while home freezers are rapidly increasing in numbers. Not only has the number of refrigerators and freezers increased in recent years, so has the average cold storage capacity,
energy consumption.

There are two types of refrigerators and freezers, manual defrost and frostless (or frostfree). The percent of these appliances that are frostless has also been increasing, reaching 70% of sales in 1974[2]. Bacause of heating requirements to prevent ice formation, frostless freezers consume about 30%[3] more energy than corresponding manual defrost modes. This may, in some instances, even range as high as 50% more.[4] It will be assumed for purposes of this study that nearly all freezers and refrigerators sold in the future will be of the frostless type.

Hittman[5] believes that little improvement can be made in basic refrigerator design, but analysis for the ETIP program of NBS[6] drew the opposite conclusion. This analysis is based upon a study by Chow[7] of refrigerator efficiency. He notes that although the overall trend has been towards the use of more inefficient refrigerators, i.e. frostless and larger capacity the efficiency of frostless refrigeration of the same size is becoming greater. For instance, there has been an efficiency increase of 20% in top mounted units and 5% in side by side units between 1955 and 1972. A study for Consumer Reports[8] highlighting that improvements in the efficiency of some models are possible.

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[1] Chow, 1972.

[2] Merchandising Week, February 1974.

[3] Booz, Allen, 1973b.

[4] Hittman, 1973.

[5] Ibid.

[6] Booz, Allen, 1973b.

[7] Chow, 1972.

[8] Consumer Reports, 1969

There are four possible technical improvements in the efficiency of frostless refrigerators and freezers.

- Increasing the amount and quality of insulation material. Fiberglass is currently used in many refrigerators, but is less efficient than urethane foam used in others.
- Cooling the compressor case with defrost water. This removes waste heat generated by system inefficiencies.
- Using the refrigerant to cool the motor wastes cooling energy. Eliminating this function should save energy. Adequate air circulation can perform the same function.
- Eliminating "mullion" and defrost heaters. Valve arrangements can eliminate the intermittent use of defrost heaters. Essentially, this involves reversing the roles of condenser and evaporator during the defrost phase. "Mullion" electrical resistance heaters, which prevent condensation around doors, can be replaced by condenser tubing around doors.

Figure II-12 taken from the ETIP report[1] shows the amount of energy consumption reduction for each of these measures and increasing motor efficiency results in a net energy savings of up to 56% per unit. It will be assumed that implementation of these four improvements will begin in 1976 and that all units sold beginning at that date are frostless.

It should be noted that a new line of frostless refrigeration recently introduced by Philco Ford already uses 33% to [illegible] less energy than comparable models by utilizing two of the

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[1] Booz Allen, 1973b.

FIGURE II-12

Motor Efficiency = 76.7%

Energy Required (kwh/yr)

Measure	Before	After	Savings	% Savings
Insulation	1600	1420	180	11.22
Cooling Compressor	1600	1489.5	110.5	6.88
Decreased Superheat	1600	1080	520	32.5
Replace Defrost & Mullion	1600	1227.8	372.2	22.3

Source: Booz Allen, Applied Research, Experimental Technology Incentives Program Procurement Plan 3: Stimulating Increased Efficiency in Frostless Refrigerators Through Federal Government Procurement Action, NBS-GCR-ETIP 30-06, COM-74-10258, Final Report, November, 1973

above recommendations, improved insulation and elimination of mullion heaters. Furthermore, these units sell at the same price as equivalent models. Based on a projected 56% reduction in per unit energy, savings for refrigerators and freezers of up to 1586 trillion BTUs in 1990 are estimated in Appendix B of this report.

Stoves and Ovens

In a typical home, it has been estimated that stoves and ovens represent a heat source with just under 70% of the capacity of the central heating system.[1] Of course, they rarely reach this capacity because of intermittent and partial use. Overall, home cooking represented 5.5% of residential energy consumption in 1970.[2]

Top burners of ranges are from 30% to 70% thermally efficient.[3] This thermal efficiency is dependent on both the type of fuel and design of the cooking utensil. Electric burners tend to be more thermally efficient than gas burners but the primary efficiency, that is, the efficiency related to total fuel usage including that of electric power generation, is greater for gas burners. Most of the modification for increased efficiency of top burners relate to redesign of cooking utensils rather than the burners themselves and would therefore be difficult to implement.

Typical oven units are subject to large heat losses. At 400°F these may approach 4000 BTU/hour. Improved insulation in oven walls and around doors could eliminate over 1100 BTU/hour of this heat loss.[4] Replacing gas pilot lights with electric ignition could greatly reduce one wasteful use of fuel. Hittman estimates that these two technical innovations could reduce range consumptions about 25% for gas ranges.[5]

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[1] Hittman, 1972

[2] MATHEMATICA estimates based on SRI, 1972.

[3] Hittman, 1973. Thermal efficiency here is defined as the ratio of energy delivered inside the cooking utensil to energy available from the burner.

[4] Hittman, 1973

[5] Hittman, 1973

Self-cleaning ovens are a recent innovation which require about 3KwH of electricity during the operation of the cleaning cycle. For one cleaning cycle per month, this represents about a 3% increase in the energy required each year for operation. Increased insulation is necessary because of the elevated temperatures of up to 950°F used for the cleaning cycle. According to Hittman[1], there are indications that this increased insulation can result in increased oven efficiency during use of the oven for baking. Whether a self-cleaning oven saves energy over a conventional unit depends on the frequency of cleaning cycle use and amount of extra insulation actually installed.

It should be noted that inefficiencies in the design of cooking units increase the need for air conditioning in the summer. Eliminating gas pilot lights, improving insulation and installing outside vents on ovens could potentially reduce this load, but these effects will not be considered in this study.

Based upon an assumed 25% reduction in per unit consumption for all new ranges, potential energy savings below would result. Appendix B shows the methodology of the calculations which yield these results.

YEAR	1977	1980	1985	1990
ENERGY SAVINGS (trillion BTU)	29	71	130	177

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[1] Hittman, 1973.

[2] Ibid.

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

This measure represents a binary situation in which the maximum energy savings would probably be realized if the measure were implemented; however, as described below, the chances seem remote that such a measure would be federally enacted. In other words, it seems to be an "all or nothing" situation.

According to both the Association of Home Appliance Manufacturers (AHAM) and the National Bureau of Standards (NBS) appliance labelling task force, there would be great negative reaction on the part of manufacturers to mandatory federal energy efficiency standards. The industry has already undertaken a voluntary appliance rating and labelling program (supervised by NBS): air conditioners and freezers should be labelled by early 1975, with other major appliances to follow.

However, considerable doubt was expressed, especially by NBS, regarding the feasibility of enacting, administering, and enforcing minimum federal efficiency standards--only allowing those appliances to be sold which met the standards. Because of this infeasibility, the minimum federal standards part of the implementation strategy would probably prevent implementation of this measure.

There are a number of present and potential legal precedents related to this measure. New York City apparently has passed an appliance rating and labelling ordinance requiring appliances sold within the city to be labelled with their industry-determined efficiency ratings.[1] Senate Bill 2176 also has a similar provision for appliance rating and labelling, although the bill is given only a 50% chance of passage. A recently enacted California law, however, requires not only efficiency rating and labelling but establishes a commission to set and enforce minimum standards.

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[1] Source: National Bureau of Standards appliance labelling task force.

The NBS task force spokesman also commented that a large bureaucratic administrative structure would be necessary to test and rate all the different appliance models and to arrive at minimum acceptable standards. At present, there are no federal agencies equipped to handle such a large volume ongoing program.

In addition to the strong objections of the appliance industry, there would probably be some negative impact upon the consumer. According to AHAM and NBS, more energy efficient appliances are generally larger, as in the case of air conditioners, and/or more expensive because of additional energy conserving materials, as in the added insulation in hot water heaters. This would mean that many of the smaller (i.e., more convenient or portable and cheaper appliance models would go off the market if minimum federal standards were applied. Until manufacturers could design new, more efficient, and less expensive models and until these new models reach the market (2 to 3 years, according to AHAM), some consumers might be inconvenienced.

The estimate of feasible energy savings has been assumed to be 100% of maximum potential for purposes of the impact estimates. If the measure were to be implemented, total savings between 1977 and 1990 would be approximately 23,288 x 10^{12} BTU's as shown in Table 3.

IMPACTS

Figure II-13 summarizes the impacts.

FIGURE II-13

IMPACT SUMMARY - APPLIANCES

	Annual Impact 1977	1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	865	1,348	2,221	2,863	23,288
2. Estimated Feasible	865	1,348	2,221	2,863	23,288
B. Impacts (Millions of Dollars)					
1. Private Industry					
Appliance Industry		Insufficient Data			
2. Private Consumer Savings	$3,591m	$6,476m	$13,015m	$16,748m	$148,323m
3. Public Sector					
Government		Insufficient Data			
Balance of Payments	$. 68m	$115m	$195m	$234m	$2,272m
4. Employment (Jobs)					
Appliance Industry		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	2.4%	2.6%	3.3%	2.7%	

Private Consumer

Cost savings which could accrue to the individual consumer as a result of increased appliance efficiency are estimated as follows:

	Annual Unit Consumption BTUx10^6	Cost Per BTUx10^6	Operating Cost	Percent Savings	Savings
Hot Water Heaters	12.44	$3.17[1]	$39.43	24.5	$ 9.66
Air Conditioners					
Room	5.24	5.86[2]	30.71	42.5	13.05
Central	13.92	5.86[2]	81.57	17.5	14.27
Refrigerators	5.12	5.86[2]	30.00	56.0	16.80
Freezers	5.2	5.86[2]	30.47	56.0	17.06

Total savings for 1977 through 1990, obtained from the application of the BTU unit costs, are presented below:

	1977	1980	1985	1990
Hot Water Heaters	$1,610m	$1,677m	$ 3,820m	$ 4,243m
Air Conditioners				
Room	346m	680m	1,178m	1,588m
Central	287m	604m	1,125mm	1,623m
Refrigerators	557m	1,447m	2,836m	3,768m
Freezers	791m	2,069m	4,055m	5,526m
TOTAL	$3,591m	$6,476m	$13,015m	$16,748m

Public Sector

The public sector costs associated with this measure would be for the administrative expenses of federal agencies responsible for enforcing the minimum appliance efficiencies. Primarily involved would be the Federal Trade Commission and the National Bureau of Standards. FTC's incremental expenses would be minimal because that agency is already involved in enforcing consumer product standards.

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[1] National average cost for gas and electric heaters.

[2] National average cost for electricity.

The bonus of the program would have to be absorbed by NBS which would have to test each new appliance model for all manufacturers. Considerable manpower and materials expenses could be encountered in this operation. NBS spokesmen indicate that while exact costs could not be projected, the incremental expenses would be considerable.

Assuming approximately 18% of oil required is imported, and estimated $2.3 billion in oil imports would be avoided between 1977 and 1990 as a result of this measure.

Resource/Materials Effects

There are no apparent critical resources or material problems associated with this measure.

Quality of Life

One major impact to quality of life would be the improved operating efficiency of the different appliances. For example, air conditioners should provide cooler rooms and ovens should retain more stable temperatures. However, there are indications that some appliances will be heavier, bigger, and noisier. Since sufficient data were not available for the analysis, however, a quantitative assessment could not be provided.

Environment

The appliance efficiency measure could result in a significant overall contribution to sulfur dioxide reductions, since this measure affects electrically powered appliances instead of gas and oil fixed heating and cooling devices.

A relatively small fraction of electricity is produced by low pollution natural gas (approximately 17%), and projections[1] indicate that this fraction will diminish to less than 5% by the end of the century. Hence, for an electrically based measure such as this one, reduced pollution effects can be as high as 2.7% of all energy sources by 1990.

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[1] Reference Energy System and Resource Data for Use in the Assessment of Energy Technology, Associated Universities, Inc., April 1972.

Private Industry

Based upon conversations with appliance manufacturers, the efficiency measures proposed should not impact the price and sales of most appliances over the long term. For example, one manufacturer of refrigerators has a new refrigerator on the market which complies with the proposed efficiency measures. This unit is priced at the same level as the old model - proving that, at least in one case, it is possible to have energy efficiency at the same cost.

The only major exception could be the price and sales of window air conditioners; as discussed earlier, experts believe that increased efficiency standards will eliminate the smaller and less expensive units. This will have the impact of raising overall air conditioner price levels. While demand elasticities cannot be determined for each size unit, data from the Association of Home Appliance Manufacturers illustrate that there is a strong demand for the small units; i.e., in the under 9,000 BTU range.

Insufficient data were available to determine elasticity or in-elasticity for any of the major appliances. As a result, for purposes of the analyses, sales of each of the units have been assumed to be in-elastic.

Employment

The manufacture of more efficient appliances will entail design modifications at the factory which should not significantly impact on level of employment.

F. THERMOSTAT SETTING TO CONSERVE ENERGY

1. Maximum Energy Savings

The life style of the inhabitant has a major impact on the energy consumption of the housing unit. People use energy differently, even in housing units of similar design. The numbers and types of appliances vary, appliances are used differently, the number of residents could vary, and the preferences for personal comfort are different. For example, a study by Hittman Associates, Inc.,[1] showed up to 30% variation in heating requirements of similar sized houses (Figure II-14). Another study by Princeton University,[2] of the Twin Rivers Housing Development in New Jersey also found wide variations in the amounts of energy consumed in identical housing units at the same location.

One of the principal ways in which people influence energy consumption in a house is by setting the thermostat. This directly affects the amount of heating or cooling energy used in a home. The annual amount of energy for home heating depends upon the number of degree days in a year. The degree day contribution for a particular day is that day's average temperature subtracted from 65°F. Thus a day with an average temperature of 50° would have a contribution of 15 degree days. A study by Honeywell which was analyzed by Hittman[3] utilized a computer simulation methodology and estimated that 1-2% of the energy for winter heating could be saved for each degree the thermostat is lowered. For the purposes of this report, a 7° winter heating thermostat setting decrease from 75°F to 68°F is assumed, as recommended by the Federal Energy Administration. This should result in a 9.4 reduction[4] in unit heating fuel requirements and applies across the board to all types of heating units.

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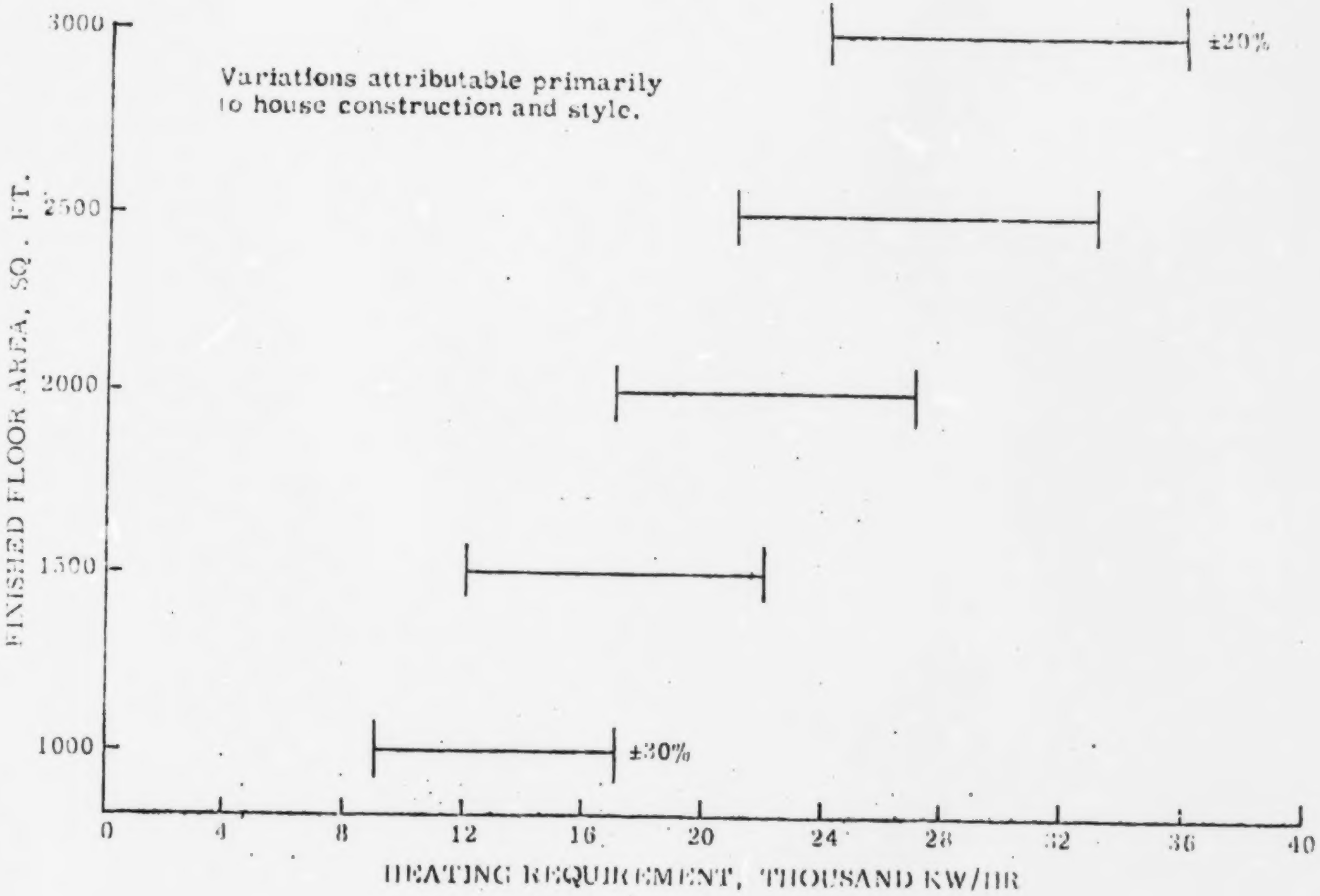
[1] Hittman, 1973

[2] Grot and Socolow, 1973

[3] Hittman, 1973

[4] MATHEMATICA estimate based on Hittman, 1973

Figure II-14



Annual Electrical Heating Use Pattern Versus Floor Area

Source: Hittman Associates Inc., Single Family Housing Final Report, HUD-PDR-29-2, March, 1973

The calculation of per unit energy savings from raising the summer temperature and thus reducing air conditioning use presents difficulties in calculation. One method of calculation is to use the "cooling degree day" method. This method calculates "cooling degree days" in a similar manner to degree days used for heating. Instead of 65°F, this method uses a base temperature which is the desired indoor temperature minus 5°F. Thus a temperature setting of 78°F would have a base temperature of 73°F. Cooling degree days for three cities as well as for a national average were calculated by Tansil[1] for different based temperatures. Using this data, he estimated that approximately 40% of air conditioning energy could be saved by the use of raising air conditioning temperature use from 75°F to 80°F.

This approach, however, neglects many of the factors which contribute to the use of air conditioning. Unlike heating use, which depends primarily on the ambient outside temperature, air conditioning use depends upon several additional meteorological factors, such as relative humidity, wind velocity, and solar heating effects. Also, as a practical matter, many air conditioners are not controlled by the use of thermostats; they are simply turned on when the occupant feels the need. The decision to use air conditioning, while influenced by meteorological factors, is thus a very subjective one. A number of scales have been developed by electric utilities which are used to predict the air conditioning load for residential housing. These, however, are based on local meteorological data and thus cannot be readily generalized to other sections of the country.

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[1] Tansil, 1973

It would be difficult to use these methods as a method for analysis in a study of thermostat setting. There is a difference between the use of a predictor of energy consumption based upon constant behavioral patterns and the use of that predictor to determine the effect of changing behavioral patterns. The National Bureau of Standards[1] estimates that raising the temperature at which air conditioning is used from 74°F to 79°F[2] would eliminate approximately 15% of air conditioning energy usage. This estimate is based upon engineering judgment rather than hard data, but is used in this report as the unit basis for energy savings calculations.

Based upon the above estimates that 9.4% of home heating energy and 15% of home cooling energy can be saved, the following potential energy savings arise (in trillion BTU's):

	1977	1980	1985	1990
Heating	787	841	921	1009
Cooling	108	126	158	186
Total	895	967	1079	1195

This energy savings potential is found by applying the average percent savings factors to the total projected energy demand for house heating and house cooling shown in Appendix B .

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[1] NBS, 1973

[2] The FEA conservation campaign suggested the use of 78°F as the summer temperature. However, since the NBS study had estimated the savings at a higher temperature, those figures were used in this study.

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

A public opinion survey sponsored by EPA indicated that 60% of the people surveyed would lower/raise thermostats in response to public appeal for easing the fuel shortage. Based on this survey, which represented the only quantitative data available, it has been assumed that a maximum of 60% compliance can be achieved. As shown in Figure II-15, approximately 8128 trillion BTU's would be saved between 1977 and 1990.

There are two caveats to this estimate:

a. Actual compliance could easily fall below 60% because not all survey respondents who favored thermostat setting will comply in practice.

b. The reduced estimates do not consider initial start-up time of a campaign, plus time for establishment of an administrative structure necessary to run a national education and public appeal program. While these considerations might reduce the level of participation in the initial implementation years, it is uncertain whether savings can be sustained over the long term.

IMPACTS

Figure II-15 summarizes the impacts.

Private Consumer

As described earlier, raising thermostats in the summer and lowering them in the winter would result in a 15% reduction of annual household operating costs for air conditioners and a 9.4% reduction for annual heating costs for the consumer. Average energy bills for air conditioning and heating were assumed at $46.00 and $166.00 respectively . The average annual savings per household is computed as follows:

	Percent Savings	Cost	Savings
Air Conditioning	15.0	$ 46.00	$ 6.90
Heating	9.4	166.00	15.60
Total		$212.00	$ 22.50

Figure II-15

THERMOSTAT CONTROL IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	895	967	1,079	1,195	14,643
2. Estimated Feasible	537	383	647	717	8,786
B. Impacts (Millions of Dollars)					
1. Private Industry	No Significant Impacts				
2. Private Consumer Savings	$ 1,568	$ 1,690	$ 1,873	$ 2,073	$ 25,512
3. Public Sector					
Government	($0.1m)	($0.1m)	($0.1m)	($0.1m)	($1.4m)
Balance of Payments	$54m	$58m	$65m	$72m	$879m
4. Employment (Jobs)	No Significant Impacts				
5. Environment (Percent Reduction)					
SO_2 Reduction	.14	.14	.12	.11	

The foregoing estimate equals approximately $2.9/MMBTU saved or a total of $8.8 billion between 1977 and 1990. There would be no capital cost requirements to consumers.

Public Sector

The public sector cost associated with adjusting thermostats are the cost of promoting public awareness. Techniques could include media presentations, consumer information brochures and classroom materials for school children. Much of the media presentation is done through public service broadcasts, which are at no cost to the government. However, there are administrative and direct expenses associated with the bureaucratic operation of the program. FEA estimates that direct expenses for the "Don't Be Fuelish" campaign in FY 1974 were $400,000, of which $100,000 could be attributed to promoting thermostat adjustments.

Assuming approximately 18% of oil supply would be imported, approximately $879 million in oil imports could be avoided between 1977 and 1990.

Scarce Resource/Materials

There are no critical resources or materials problems associated with this measure.

Quality of Life

There are data to indicate that some negative comfort impact would result from this measure. In the Nevins and Rohles study, the following scale was developed for average subject reactions to temperature levels, based upon constant relative humidities of 40 and 60 percent and for temperatures ranging from 65°F to 92°F:

Comfort Scale	Degrees at 40% humidity (Summer)	Degrees at 60% humidity (Winter)
1. Cool	66°	64°
2. Slightly cool	72	71
3. Comfortable	78	77
4. Slightly warm	86	84
5. Warm	93	91

If it assumed that thermostats would be raised from 74°F to 78°F in the summer, for the recommended conservation measure, the impact as reflected by the subjects in Nevins and Rohles' tests result in a change from "slightly cool" to "comfortable".

Again if it is assumed that, in the winter thermostats would be lowered from 74°F to 68°F, test subjects indicated this temperature would be regarded as somewhat between "slightly cool" and "cool," a one point drop on the Nevins and Rohles scale. Hence, no discernable impact is recognized for summer changes and a slight discomfort impact would be incurred during the winter.

Environment

The sulfer dioxide (SO_2) reductions realized from implementation of this measure are less than one percent of total SO_2 emissions, but on the order of three percent of the SO_2 emissions resulting from residential heating and cooling. This latter figure is of moderate significance in reducing local SO_2 concentrations in residential areas.

Private Industry

Reduced home energy consumption as a result of thermostat regulation will reduce gross revenues of gas, electric utilities and home oil industries. No other residential sector impacts are anticipated.

Employment

No significant employment effects are anticipated from the implementation of this measure.

G. USE OF SOLAR ENERGY AND/OR HEAT PUMPS[1]

1. Maximum Energy Savings

The potential for using solar/heat pump technology for residential use is currently a major consideration as part of a long term solution to the nation's dwindling fuel supplies. In this section of the study, the use of solar/heat pump technology as a conservation measure is analyzed, particularly for space heating applications. In making this analysis, it is important to consider the full range of solar/heat pump technology for comfort heating:

- Air Source Heat Pump
- Full Solar
- Solar Assisted Systems

Appendix B contains a detailed technical description of all the systems analyzed in this study. The use of solar energy to generate cooling is not considered to be a significant development for the 1977 - 1990 time period. Absorption refrigeration units which can generate chilled water with 200°F water input are available as an energy source.[2] However, the efficiency of solar collection to provide this very hot water is very low. There improvements increase cost and technology improvements are required.

As shown in Figure II-2, house space conditioning and hot water are the most significant uses of residential energy and probably offer the greatest opportunity for conservation. Given the requirement for large amounts of thermal energy in the range 80-150°F for these uses, we need to examine the technologies likely to result in the best energy utilization given resources available. Two such technologies are heat pumps and solar energy.

The space contioning system can be thought of as a converter - it takes high quality energy - electricity - and converts it to thermal energy. An electrical resistance heater produces 1 BTU of thermal energy for each BTU of electrical input, i.e. its coefficient of performance (COP)[3] is one. However, if we were to of electricity to obtain one BTU of thermal output. Some of the technical factors that limit heat pump performance are discussed in Appendix B. It is seen there that for air source heat pumps a COP of up to 2.6 is achievable, while water source heat pumps can give COPs of up to 4.0. Thus it can be seen that the use of an improved converter such as a heat pump allows the direct use of electricity as an end point fuel but with usage levels well below those encountered for resistive heat.

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[1] This section is based on a report prepared by Dr. H. L. Brown and Dr. B. B. Hamel for MATHEMATICA, Inc. (Brown and Hamel, 1974).

[2] NSF/NASA, 1972.

[3] The coefficient of performance (COP) of a heating system is defined as the ratio of heat energy produced by a system to the input energy.

Solar energy is the use of an inexhaustible natural energy form available to the user directly in the form of low temperature energy. By the use of low temperature collectors (see Appendix B), it is possible to make hot air or hot water directly available for space conditioning or hot water without any intermediate steps.

Heat pumps are electric or heat operated refrigerators or air conditioners operating in reverse. They warm the house by cooling the out-of-doors. Mechanical energy, generally from electric motors, is used to bring in "free" but low temperature energy from the environment (outside air) and pump it up to warmer temperatures required for heating.[1]

For every BTU a heat pump consumes in electricity, it produces up to two in heating for a house. This compares with the one BTU of energy provided by electric resistance heaters for every BTU consumed in the house and approximately three BTU of fuel consumed at the electric power plant (assuming a 33% power plant efficiency). The use of the heat pump for space heating (and cooling when they are reversed) has to date been economically feasible only in the Southern regions of the country, but higher prices will make it economical in most regions of the nation[2]. The relatively higher winter temperatures in the South allow for more efficient heat pump operation (See Appendix B).

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[1] Hamel et al, 1972.

[2] Brown and Hamel, 1974.

Basic characteristics of the air source heat pump are described in Appendix B. As the ambient temperature decreases the COP of the heat pump decreases, so that for regions further north the heat pump performance deteriorates: a typical COP for Atlanta can be 2.2, while for Philadelphia it will be 1.6 and Minneapolis 1.3. In general the cost of an air source heat pump will be about 10% greater than an air conditioner of comparable size, as additional controls are required. So that a house with electrical resistive baseboard units and central air conditioning will have a first cost that is 10% less than the ASHP. Operating costs and energy savings, compared to resistive heat will be given by the relation: $(1 - \frac{1}{COP})$ as the percentage savings. The savings are estimated to average 30%.[1]

b. Full Solar Systems

Residential dwellings may be heated and cooled with solar energy by use of systems using solar collectors of radiant energy such as the examples shown in Appendix B. The possibility for solar cooling is limited[2] and will not be explored in depth due to the major research and development still required.

Because of the varying conditions of temperature and solar radiant energy, solar systems - even full solar systems - need a back-up or auxiliary conventional system. Such auxiliaries are usually built into the building.

There are two major components of the solar part of all systems; the solar collector and the thermal storage system. The solar collector functions to capture the sun's radiant energy while the thermal storage system holds the energy and distributes it where it is needed.

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[1] Brown and Hamel, 1974.

[2] See, for example, Swartman et al, 1973 & Thomason et al, 1974.

Over 20 experimental solar heated structures of various types have been designed, built and operated. Some of these are listed in Appendix B. Workable heating systems have evolved from these experiments. However, they are not all fully engineered, both from the point of view of selecting the best systems or optimizing the design of those systems. Solar collectors, energy storage elements and heat transfer systems are in a relatively early stage of component development and engineering.[1] Technical feasibility appears assured; however, economic feasibility has yet to be demonstrated. Significant research and development is required to reduce cost and develop significantly improved and engineered systems.

A full solar system will in general involve the low temperature collection of solar energy (150°F) in flat plate collectors located on the roof.[2] The fluid that circulates through these collectors will then contact with a basement storage system and from this system either a hot water or hot air loop will provide space conditioning. In general, four days of winter storage will be necessary and a backup electrical resistive heater will be required as an insurance measure. It is estimated that the average unit will produce a 95% savings over an electric resistance unit.[3] A further discussion of the design considerations and economics of full solar systems is given in Appendix B.

c. Solar Assist/Hybrid Systems

As indicated in Appendix B, both solar technology and heat pump technology have their own unique problems. The main difficulty suffered by solar technology is economic:[4] if one attempts to provide all thermal requirements by solar energy the first cost becomes very high.

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[1] University of Pennsylvania, 1973, 1974, NSF/NASA, 1972 and Swartman et al, 1973.

[2] Brown and Hamel, 1974.

[3] Ibid.

[4] See, for example, NSF/NASA, 1972, University of Pennsylvania, 1973, University of Maryland, 1973, and IECEC, 1972-1973.

Combination solar/heat pump systems can achieve a high performance with significant energy and cost savings, particularly when the COP is as high as 3 to 4. This occurs because the energy efficiency limitations of both systems are eliminated when the two are combined. A full description of this effect is given in Appendix J. The range of possible systems in this class is wide and may include:

- resistive heat with solar assist
- fossil fuel heat with solar assist
- conventional heating with solar domestic hot water
- solar assisted heat pump

Among these, the two that seem most promising are conventional heating with solar domestic hot water, and solar assisted heat pump. The former will be of considerable interest in southern areas where insulation is favorable.[1] Its use involves a modest first cost: $450-$900, depending on solar panel costs and involves perhaps 80-100 sq. ft.[1] of solar panel area. Commercial availability of units can be expected in the immediate future.

The second option seems to offer the best prospect for a solar assist system for space conditioning as well as hot water. In this system, the residence must have a conventional heating system, and the solar energy system is added to that conventional system to reduce fossil fuel or electric energy consumption.[2] The solar energy that is collected is used to raise the temperature from which the heat pump takes energy. By using a water source heat pump, higher COP's can be achieved due to better heat transfer. Because solar energy is used, not to directly space condition, but to energize the heat pump, it may be collected at 90-100°F rather than 134-150°F. This allows significantly higher collection efficiencies (See Appendix J), and therefore less solar area per BTU collected. In addition, the water loop system allows one to collect the waste energy available in the house generated from internal energy sources.

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[1] See Calver, 1973.

[2] Brown and Hamel, 1974.

In general, this system is of some interest because it seems possible here to overcome the deficiencies of the solar and heat pump systems with this hybrid and can lead to savings of as much as 60% of the space heating energy.[1]

b. Calculation of Potential Energy Savings

Since electricity will likely be the main source of energy in new construction in the future, the air source heat pump offers the best prospect for an immediate 30% saving in energy with first cost increases that are modest.

Solar hot water heating is probably now practical in Florida and California, and we can expect practical commercial systems in the near future.

Solar assisted space conditioning is promising, especially solar assist water source heat pumps. However, significant development and field testing are required.

The economics of these systems look promising: amortized $/MBTU costs are competitive with fossil fuel costs and incremental first costs are not excessive.

Based on Brown and Hamel (1974), the following assumptions have been made for expected rate of implementation of the three types of systems over the period considered in this study.

Air Source Heat Pump	Applied to	Expected Per Cent of New Houses in Year				Average % Savings per Unit
		1977	1980	1985	1990	
a. ASHP	New electrically heated homes	5%	10%	20%	35%	30%
b. Solar Assisted Systems	All new homes	0%	2%	6%	15%	60%
c. All Solar	All new homes	0%	0%	3%	10%	95%

Appendix J explains in detail the methodology used to calculate the aggregate energy savings for each system. The total energy savings in each year for all three systems combined is 12, 56, 256 and 683 trillion BTU's in 1977, 1980, 1985 and 1990 respectively.

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[1] (Brown and Hamel, 1974)

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

Factors to be considered in assessing the feasibility of this measure include: 1) estimated potential energy savings and market penetration for each system; 2) the radical attitude change regarding solar energy necessary on the part of home owners, home builders and banks making mortgage and home improvement loans and 3) the lack of precedent for personal tax credits.

Although not directly applicable to this measure, there is a solar energy development and demonstration bill (H.R. 11864) which has passed both houses of Congress. (The bill would fund a relatively small scale residential solar energy heating demonstration program over a three-year period.) However, the committee reports for the bill indicated that the largest single obstacle to widespread use of residential solar energy heating devices was the outlook of home owners, builders, and banks who tend to view solar energy systems as too futuristic.[1] In addition to tax credits, therefore, some type of public education would have to be undertaken to reach even the percentages of market penetration shown.

In the case of electric heat pumps, which would be used in tandem with solar energy collectors in this measure, there has been a past history of equipment failures in the defrost mechanism and lack of manufacturer's guarantees which have generally made consumers hesitate to buy them. The heat pumps have been improved through research (notably by the Edison Electric Institute); however, consumers might have to be educated as to their reliability.[2]

Another major feasibility factor in this measure is the lack of legal precedent in allowing tax credit for personal home improvements and the necessity of new legislation and regulations to safeguard against abuse and to define "accredited" solar/heat pump systems. There are, however, existing agencies such as the IRS and state income tax agencies, which could administer such a program.

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[1] Source: H.R. 11864, p. 18.

[2] New York, 1973.

At present, there is no industry to handle the design and mass manufacturing of low-cost, reliable solar equipment.[1] However, given the timeframe of four years between 1976 (year of implementation) and 1980 it was assumed that a solar energy/heat pump industry could have adequate facilities and materials processes developed by 1980 to meet demand.

IMPACTS

Figure II-16 summarizes the impact.

Private Consumer

The implementation of solar heat pumps is considered only for new homes. Hence, consumer impacts will affect only those persons purchasing or renting a new dwelling unit.

The capital cost associated with solar systems for average house size is estimated as follows:

	Capital Cost	Added Capital Cost[2]	Annualized Capital Cost[3]
Solar/heat pump	$ 900	$ 50	$ 4.44
Solar assist	2,200	700	77.50
Total solar	9,000	4,100	364.00

Assuming annual home heating costs of $166 per year under traditional systems, heating cost savings for ASHP would be 30% or $50, solar assistance would be 60% or $100 per year and full solar would be 95% or $158 per year. When compared to annualized capital cost each with the exception of full solar, represents a cost savings to the consumer. Assuming full solar implementation in colder areas with heating costs in excess of the average $166 per year (e.g., $500) would result in a cost savings.

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[1] Source: H.R. 11864, p. 17.

[2] Assumes $800 for conventional systems and a 50% tax credit.

[3] At 8% mortgage over 30 years.

Figure II-16

S[illegible] HE[illegible] ASS[illegible] NC[illegible]

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTU sx 10^{12})					
1. Maximum	12	56	256	683	3,577
2. Estimated Feasible	12	56	256	683	3,577
B. Impacts (Millions of Dollars)					
1. Private Industry					
Average Annual New Solar Industry Revenues	$56m	$346m	$ 1,248m	$ 5,377m	$ 34,276m
Average Annual Furnace Industry Revenue Loss	($50m)	($225m)	($ 497m)	($1,043m)	($ 8,478m)
2. Private Consumer					
Savings	$17.3m	$80.6m	$368.0m	$983.5m	$5,151m
Annualized Capital Cost	($.1m)	($19.9m)	($191.0m)	($729.0m)	($3,222m)
Net Savings	$17.2m	$60.7m	$177.0m	$254m	$1,929m
3. Public Sector					
Government (Annual Average)	($.3m)	($ 6.5m)	($52.8m)	($108.6m)	($732.8m)
Balance of Payments	$ 1.4m	$ 5.6m	$25.6m	$68.3m	$358m
4. Employment (Jobs)					
New Solar Industry		Insufficient Data			
Furnace Industry		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	.0026%	.011%	.034%	.084%	

Finally, without the tax credit, with the exception of high heat cost areas, both total solar and solar assist system costs, at the present state of the art could represent a net cost to the consumer. Under this situation only high heat cost areas would represent potential markets for solar systems.

However, based upon the average heat cost of $166/year and assuming a tax credit, consumers would save almost $2.0 billion between 1977 and 1990 as a result of this measure.

Public Sector

As a result of the proposed tax credit, the government could lose approximately $732 million in tax revenues between 1977 and 1990. However, it should be pointed out that without the tax credit, potential implementation could be severely limited.

As a result of decreased energy use, home heating oil fuel consumption and electric power oil requirements would be reduced. The reduction could result in the avoidance of $358 million in oil imports.

Quality of Life

No major changes are anticipated for this measure.

Materials/Resources

According to Dr. Ronald Lawson, Office of Technology Assessment, the development of a solar systems industry could result in a shortage of cadium. In this case, both final cost and rate of implementation would be impacted, but this is based on the development of solar electric cell technology, different from that discussed here.

Environment

Ten percent reduction of SO_2 emissions resulting from new residential heating/cooling energy sources could be achieved. This estimate could represent approximately .08% decrease in all SO_2 pollution.

Private Industry

Two primary impacts would be incurred: a new solar heat pump industry would be established and the existing home heat industry would lose revenue. In the case of a new solar/heat pump industry, it is estimated that total gross sales could be as high as $34 billion for new homes between 1977 and 1990. Retrofit is not considered. Data availability does not permit a judgement on possible return on investment. The existing home heat industry could lose up to $8.4 billion in traditional furnace sales.

Employment

Present data does not permit the estimate of changes in employment that would result from a new solar/system industry.

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III. ENERGY CONSERVATION IN THE INDUSTRIAL SECTOR

A. INTRODUCTION

The industrial sector is a major consumer of energy in the U.S., having accounted for approximately 30% of the total energy consumption in 1970.[1] It is also widely felt that due to past low fuel prices, little attention has been given to efficiency of energy utilization. Therefore, the industrial sector should receive a considerable amount of attention in any study of energy conservation potential.

Unfortunately, there is little accurate and detailed information on the specific end uses of energy in the industrial sector. There are many different uses of energy in each industry, and to date, there have been few significant and comprehensive data collection efforts to try to determine how much and what type of energy is consumed for what specific purpose. There are two major sources of nationwide data on energy consumption by the industrial sector: The Bureau of Mines Mineral Industry Surveys and the Census of Manufactures. The Bureau of Mines reports data on fuel consumption only for the industrial sector as a whole and not by industry or type of end use. Although the Census of Manufactures data reports energy consumption by industry, it does not report data by end use except to separate raw material use from heat and power use.

The only source of information which gives any data on energy consumption by end use (direct heat, steam, space heating, electrolysis, electric drive, etc.) is the report prepared by Stanford Research Institute.[2] This source was used in the analysis.

Based on an analysis of the available literature, the following measures were selected for analysis. These are summarized in Figure III-1.

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[1] MATHEMATICA Energy Data Base.

[2] SRI, 1972.

FIGURE III-1

ENERGY CONSERVATION MEASURES - INDUSTRIAL SECTOR

Serial No.	Conservation Measure	Implementation Strategy
I-1	Increasing the efficiency of direct heat and steam raising	Not considered*
I-2	Increasing efficiency of energy intensive processes	Not considered*
I-3	Increased recycling of energy intensive materials	Federal legislation supplying subsidy grants
I-4	Reduced use of packaging	Federal regulation
I-5	Decreased use of non-returnable bottles	Eliminate nonreturnable beverage containers through federal regulations
I-6	Use of Total Energy Systems	Promote total energy systems use in industrial plant design through tax credits
I-7	Increase use of natural fertilizers	Voluntary means (free market mechanism)

*These measures were not considered in the Peat, Marwick and Mitchell study of impacts and evaluation and ranking.

A breakdown of the estimated 1968 industrial energy consumption by end use is shown in Figure III-2. A summary of the maximum technologically feasible savings and achievable savings is given in Figure III-3.

B. INCREASING THE EFFICIENCY OF DIRECT HEAT AND STEAM RAISING

1. Maximum Energy Savings

BACKGROUND

The analysis of energy conservation potential in the manufacturing industries was broken down into two basic parts. The first part, described in this section, dealt with energy conservation measures which were applicable to a broad spectrum of industry. These were called "horizontal" energy conservation measures and included measures applied to direct process heat, steam heat, and comfort heating in general.

The second approach was oriented towards industrial processes in specific energy intensive industries. In this case energy requirements per unit of production were available and could be used in conjunction with gross production figures to arrive at total energy consumption in specific industries. The discussion of these measures is given in Section C of this Chapter.

The following energy conservation measures were analyzed in the "horizontal" category:

- Improved steam boiler operation
- Improved direct heat processes
  - flue heat recovery systems,
  - oven/furnace instrumentation
  - insulation
  - rescheduling
  - improved "housekeeping"
- Improved comfort heating.

FIGURE III-2

ENERGY CONSUMPTION BY THE INDUSTRIAL SECTOR
BY TYPE OF USE - 1968

	CONSUMPTION (10^{12} BTU)	PERCENT OF TOTAL
PROCESS STEAM	10,132	40.6
DIRECT HEAT	6,929	27.8
ELECTRIC DRIVE	4,794	19.2
ELECTROLYTIC PROCESS	705	2.8
FEED STOCK	2,202	8.8
OTHER	198	.8
TOTAL	24,960	100.0

Source: Patterns of Energy Consumption in the U. S., Stanford Research Institute, 1972.

Figure III-3

SUMMARY OF ENERGY SAVINGS - INDUSTRIAL SECTOR

(Trillions of BTU's)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Direct Heat and Steam Raising*	2736	2896	3194	4437				
Energy Intensive Processes*	973	1060	1265	1491				
Recycling	255	293	354	428	3	15	97	214
Packaging	568	753	1047	1289	0	0	0	1289
Non-returnables	307	354	448	568	0	0	448	568
Total Energy Systems	383	418	505	592	4	21	26	148
Natural Fertilizers	65	71	75	82	42	46	48	53

*These measures were not evaluated by Peat, Marwick, Mitchell & Co. and therefore no estimates of achievable savings are presented.

Steam Boilers

The use of energy in steam boilers amounts to half of the total energy consumed by the industrial sector.[1] This fact, in conjunction with the general lack of care now being shown in the use of steam boilers, indicates that the use of steam boilers is a prime area for conserving energy in the industrial sector.

Industrial boiler operation today varies from excellent to very poor, with the majority of all boilers being inadequately instrumented. Optimum boiler operation requires knowledge and control of flue gas composition, flue gas temperatures and draft. Improper adjustment of combustion could waste 10% or more of the fuel.[2] Other "housekeeping" measures (described below) would also result in energy conservation.

For purposes of our analysis, it was assumed that 100% of the process steam energy requirement could be susceptible to the energy conservation measures described and that an average of 7.5% of the energy could be saved, thus giving an overall saving of 7.5%.[3]

Flue Heat Recovery Systems

Flue heat recovery systems provide for the use of neat wasted in the original combustion process. The following types of flue heat recovery systems were considered:

- Recuperators provide for continuous-flow heat exchange from outgoing flue products to incoming air across stationary metal or ceramic surfaces.
- Regenerators store heat in a ceramic mass through which hot flue gases are exhausted. At regular intervals the flue gas is cycled through a second such mass, while the incoming air, usually for combustion, passes through the first mass to acquire its heat.

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[1] SRI, 1972.

[2] Federal Power Commission, 1974.

[3] LeMay, 1974.

- A "thermal wheel" is a cross between the two units above, in that a slowly rotating honeycombed wheel carries heat from the outgoing hot gas stream to the incoming air stream alongside in an adjacent counterflow duct.
- Waste heat boilers (sometimes with auxiliary fuel firing systems) transfer heat from existing gases to water for the purposes of generating useful steam.
- Flue incinerators can be employed to recover heat from combustible fumes in departing hot gases and, when combined with heat recovery devices discussed above, can reduce needs for comfort heating or process fuel.
- Certain high temperature units, such as ceramic kilns, often discharge heat through ducts to lower temperature units, such as the drying ovens upstream.

Regenerators have long been employed with large glass melting (tank) furnaces, comparable melting furnaces for steel (open hearths) and for steel mill ingot "soaking pit" furnaces, and very few other occasional uses. They are costly in space, first cost and maintenance, and have been considered justified only for high temperature operations. Recent introductions of new smaller regenerators for use with combustible fume incineration have received very slow acceptance.

Recuperators, which are very common in Europe, have traditionally been confined largely to higher temperature operations in the U.S., such as for steel mill slab heaters, soaking pits and smaller glass melters. Recently, recuperators have begun to secure acceptance here for lower temperature operations, particularly in connection with flue gas incinerators for combustible fumes. Their addition to existing heat processing ovens and furnaces is taking place very slowly, even in plants such as large aluminum extrusion facilities which must recover waste heat to permit desired production increases. Forge shops can particularly benefit from recuperators.

Thermal wheels and new heat pipe recovery units are receiving somewhat better acceptance, largely through aggressive sales tactics of their manufacturers.

Waste heat boilers are a comparative rarity in this country, so much so that until very recently all such units were custom built. Although most standard boiler manufacturers believe that the market is too small to bother with, one has recently announced a line of standard waste heat boilers.

Use of the foregoing systems could be widely extended. If effectively accomplished, this should permit recovery of an estimated 10% of all process fuel. (This assumes 50% of the direct heating units can utilize flue heat recovery systems and each unit that can use one reduces the energy requirements by 20%).[1]

Added Instrumentation

Whereas most furnaces and ovens today are equipped with some instrumentation, all should have some available and most can benefit from upgraded instrumentation. The reason for this is that past low fuel prices often made it less expensive to waste fuel than to purchase costly instrumentation.

To make use of the improved instrumentation above, many furnaces and ovens require more sophisticated fuel/air proportioning systems. Manual fuel/air ratio controls should ultimately be replaced by automatic controls, with both air and fuel under pressure capable of good control over a wide turndown range.

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[1] LeMay, 1974

It is estimated that added furnace and oven instrumentation and improved controls, if properly implemented and used, can save about 5% of oven and furnace fuel. This assumes that 80% of the existing units could benefit from improved instrumentation at a saving of 6% over previous levels of energy usage.[1]

New Insulation Material

In past years, the replacement of much hard firebrick by refractory insulating bricks (IFB) brought about large fuel savings to furnace users. A new development in industrial insulation has occurred: a furnace-lining insulating wool with temperature capability of over 2000°F.

This new material cannot be used where linings are exposed to molten metal, physical abrasion or certain chemical attack. However, its substitution for refractories in dry, "quiet" furnaces has often saved one-third of the fuel used therein.

It is estimated that widespread use of the new wool linings can save about 4% of all fuel consumed in direct heat furnaces. This assumes that 20% of the energy used in direct heat furnaces could make use of this new insulation material with a savings of 20%.[2]

Rescheduling

Observations at many plants indicate that both powered machines and heat process equipment are often left running when not actually in use. Rescheduling and better operator discipline can accomplish significant savings in such cases. It is estimated that this can account for at least 1% of all process energy.

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[1] LeMay, 1974

[2] Ibid.

Improved "Housekeeping"

"Housekeeping" is a logical first step in an energy conservation program, because it involves taking better care of and making better use of what is already largely on hand. Aspects of "housekeeping" include the following:

- adjusting temperature for space heating and cooling,
- tightening structures for air and heat leaks,
- adding building insulation and storm sash,
- adding external door closers,
- turning off unnecessary lighting,
- shutting down machines when not actually being used,
- reducing exhaust air to necessary levels,
- repairing all gas, oil, steam and hot air leaks,
- repairing steam traps and returning all possible condensate,
- maintaining pipe covering and boiler, furnace and other insulation,
- cleaning of heat transfer barriers,
- adjusting combustion,
- improving plant electric power factors.

It is estimated that the adoption of such measures can lead to savings of approximately 5% of the total direct heat energy.

Improved Comfort Heating

The largest number of industrial working areas are traditionally heated by convection, either natural or forced, with heat from convectors or processes or both. One distinct disadvantage of convection heating exists in high-bay areas. Since high bays must effectively be heated before the working areas become warm except when fans blow heat directly onto the workers, much heat is lost raising temperatures of unoccupied areas overhead.

A relatively new fuel-fired system employs a combination of radiant and convection heating, whose radiant units are installed only slightly above head height in working areas. The radiant heat is beamed directly downward to heat the people and the space below. This process eliminates the necessity of first heating high bay areas overhead, and consequently saves about 25-35% of heating fuel cost.

Whereas there are few examples of replacing installed convection with radiation heating, convection heating is being accepted rather extensively for new additions. The extent to which existing units are converted will depend on government policies, such as tax credits, and the realtive costs of fuel and new lighting equipment.

It is estimated that the energy savings from this measure and general "housekeeping" measures described below could save approximately 30% of the total space heating requirement.

Maximum Energy Savings

The energy conservation measures described above are summarized in Figure III-4 for 1968. The actual energy savings is calculated in stages. First, the amount of energy consumed for the purpose which the energy conservation measure deals with is given. The various uses of energy in the industrial sector were shown in Figure III-2 with the estimated consumption in 1968. The two types of uses considered in this analysis, process steam and direct heat, account for 68.4% of the total energy consumed by the industrial sector. It is felt these two uses represent the areas with the greatest energy saving potential.

The conservation measures dealing with the use of energy for direct heat are not mutually exclusive. In order to arrive at a single estimate of energy savings, the measure is evenly distributed over the use of fuel for direct heat. In other words, if one measure affected 50% of the energy consumption, it is assumed that 50% of the energy consumed which is affected by any other energy conservation measure is affected by the given measure. Analytically:

$$ES_i = (MA_i - \frac{MA_i}{DHE} \sum_{j=1}^{i-1} ES_j) \frac{PS_i}{100}$$

where

ES_i = energy savings resulting from conservation measure i

MA_i = maximum amount of direct heat energy which can be affected by measure i

FIGURE III-4

POTENTIAL ENERGY SAVINGS RESULTING FROM IMPROVED EFFICIENCY IN 1968 BOILER & HEATING USE

CONSERVATION MEASURE	USE OF ENERGY WHICH MEASURES DEALS WITH[1]		ENERGY CONSUMED WHICH CAN UTILIZE MEASURE		ENERGY SAVINGS	
	DESCRIPTION	ENERGY CONSUMED IN 1968 (10^{12} BTU)	AS A PERCENT OF ENERGY CONSUMED FOR THE USE MEASURE DEALS WITH[4]	VOLUME (10^{12} BTU)	AS A PERCENT OF ENERGY WHICH CAN UTILIZE MEASURE[4]	VOLUME (10^{12} BTU)
Improved Boiler Operation	Process Steam	10,132	100	7,599	7.5	760
Flue Heat Recovery System[5]	Direct Heat	6,929	50	3,465	20	693
Oven/Furnace Instrumentation & Controls[5]	Most Direct Heat	6,000	80	4,800	6	288
New High Temperature Wool Insulation[5]	Some Direct Heat[2]	4,000	35	1,400	20	280
Rescheduling[5]	Direct Heat	6,929	20	1,386	5	69
Improved Housekeeping[5]	Direct Heat	6,929	100	6,929	5	346
Radiant Comfort Heating	Space Heating	853[3]	25	213	30	64

1. *Patterns of Energy Consumption in the U.S.*, Stanford Research Institute

2. Used in furnaces where material is dry, there is no abrasion, and there is not a harmful chemical reaction.

3. Assumed to be 5% of total steam & direct heat energy consumption (Page 119 of footnote 1 above)

4. Report submitted to MATHEMATICA by R. LeMay Associates

5. The estimates given for energy savings resulting from energy conservation measures applied to direct h assume each measure is applied independently. If the measures are applied jointly, see Figure III-3 for the results.

DHE = total direct heat energy

PS_i = savings as a percent of energy consumption which can utilize the measure.

This methodology applied to 1968 data is shown in Figure III-5.

The percentage savings thus derived were applied to future projections of total direct heat energy demand. This percentage is calculated to be 22.2%.

The total energy projections are based on data provided to the Federal Energy Administration by the American Gas Association staff. The total energy projection is based on the historical relationship between real personal income in the manufacturing sector. The projections of manufacturing incomes are those made by the Department of Commerce and include a wide variety of factors such as population, GNP, and industrial technology.

It should be noted that the energy projected is a "baseline" demand in the sense that it assumes a continuation of historical trends and does not account for changes in energy consuming habits. It is felt that this is the most useful standard with which to measure the potential of the various proposed energy conservation measures.

The total energy projections thus derived are shown in Figure III-6. Also shown on this chart are the projections of the use of fuel for steam generation, direct heat, and comfort heating. These are made assuming that each use will comprise the same percentage of the total energy used as based on 1968 data. The percentage energy savings for each use are applied to these demands to arrive at the projected maximum potential energy savings.

FIGURE III-5

CALCULATION OF JOINT APPLICATION OF INDUSTRIAL ENERGY

CONSERVATION MEASURES APPLIED TO THE USE OF ENERGY FOR DIRECT HEAT

CONSERVATION MEASURE	MAXIMUM APPLICABLE ENERGY USE (10^{12} BTU)	AMOUNT OF ENERGY SAVED FROM MEASURES ALREADY APPLIED (10^{12} BTU)	FRACTION OF ENERGY ALREADY SAVED WHICH WOULD HAVE BEEN EFFECTED BY CONSERVATION MEASURE[1]	AMOUNT OF ENERGY ALREADY SAVED WHICH WOULD HAVE BEEN EFFECTED BY CONSERVATION MEASURE (10^{12} BTU)	REMAINING ENERGY WHICH IS EFFECTED BY CONSERVATION MEASURE (10^{12} BTU)	PERCENTAGE SAVINGS	SAVINGS (10^{12} BTU)
FLUE HEAT RECOVERY SYSTEMS	6,929	0	1.000	0	6,929	10.0	693
CONTROLS	6,000	693	.865	599	5,401	4.8	259
INSULATION	4,000	693+259=952	.577	549	3,451	7.0	242
RESCHEDULING	6,929	952+242=1194	1.000	1,194	5,735	1.0	57
IMPROVED HOUSEKEEPING	6,929	1194+57=1251	1.000	1,251	5,678	5.0	284
TOTAL							1,535

---

[1] This fraction is equal to the fraction of the total energy consumed for direct heat which can utilize energy conservation measure.

POTENTIAL ENERGY SAVINGS RESULTING FROM IMPROVED EFFICIENCY IN INDUSTRIAL BOILER AND HEATER USE

(10^{12} BTU)

	1977	1980	1985	1990
Process Steam				
Energy Consumed	11,957	12,545	13,675	19,215
Percent Savings	7.5	7.5	7.5	7.5
Energy Saved	897	941	1,025	1,441
Direct Heat				
Energy Consumed	8,075	8,590	9,364	13,157
Percent Savings	22.2	22.2	22.2	22.2
Energy Saved	1,703	1,907	2,079	2,921
Space Heating				
Energy Consumed	610	649	707	994
Percent Savings	7.5	7.5	7.5	7.5
Energy Saved	46	49	53	75
TOTAL[1]				
Energy Consumed	29,045	30,900	33,683	47,328
Percent Savings	9.4	9.4	9.4	9.4
Energy Saved	2,736	2,896	3,154	4,437

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[1] Includes energy consumed for electric drive, electrolytic process, feedstock, and uses other than process steam, direct heat, and space heating

2. Achievable Savings and Impacts

The analysis of achievable savings and environmental and socio-economic impacts of this measure was not performed.

C. INCREASING THE EFFICIENCY OF ENERGY INTENSIVE PROCESSES

1. Maximum Energy Savings

In this measure, a number of energy intensive processes in industries such as steel, aluminum, copper, glass melting, etc. were examined. The processes considered constituted a total of approximately 30% of the industrial energy consumption in 1970.

Steel Mills

Significant fuel-saving developments in steel mills include replacement of the open hearth by the basic oxygen (BOF) process, and increased use of the continuous casting process. Greater use of recuperation at the finishing end is also a possible means of energy savings.

Replacement of open hearth furnaces by BOF units has been proceeding rapidly and is partially completed. Whereas the open hearth furnace required much fuel, the BOF process is essentially exothermic, so fuel savings are significant.

An additional development is the introduction of continuous casting which eliminates cooling of large ingots and subsequent reheating in soaking pit furnaces. Depending upon how far the process is continuous, slab and billet heating furnaces may also give way to relatively small "heat equalizing" furnaces on the line. Conversion to continuous casting is in its relatively early stages, so most all steel plants have soaking pits which can be replaced.

Aluminum

The Bayer-Hall electrolytic process for aluminum production is almost universally used, and accounts for approximately 4% of this country's electric generating capacity. Recently, Alcoa announced development of a new process expected to reduce power requirements by approximately 30%.[1]

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[1] Aluminum Company of America, 1973.

Recently, Applied Aluminum Research Corporation of New Orleans reported the Toth chemical process for producing aluminum which is claimed to reduce by about 90% the electric power required for electrolytic refinement.[1] Whereas this process has received some attention, it has received no known support from major producers and, therefore, is not being further developed. Because of this uncertainty in its development, it is not being considered as a basic energy conservation measure.

Aluminum fabricating plants also require significant quantities of fuel both to remelt for casting and to heat for hot working. Numerous opportunities for fuel conservation exist via such items as melters and reheaters without recuperating, uncovered launders (molten metal troughs) and relatively crude combustion systems without fuel gas analyses. These factors are included in the "horizontal" measures.

Copper

Many producers have developed the vertical shaft type cathode melting furnace to replace the traditional reverberating melter. Because shaft furnaces are more efficient, via transfer of heat from flue gases to incoming metal, substantial amounts of fuel are being saved and more will be as other reverberatory furnaces are thus displaced.

Many copper and brass furnaces heating solid metal for reworking can benefit from some form of recuperation. Recuperation has not been widely used in the industry and, therefore, represents a significant potential for energy savings.

Glass Melting

The glass melting industry has changed little over many years. "Tank" furnace melting, now being used, has two specific disadvantages:

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[1] Toth & Lypman, 1973.

- Waste heat recovery through regenerators would require significant investment and space as well as substantial maintenance. The regenerators do not remove all the waste flue heat.
- The glass "batch" (raw material") lies as an insulating blanket atop the first several feet of the glass, effectively blocking transfer of heat to the glass from the flames and hot arch above.

It has been suggested that the costly regenerators be eliminated, that the glass batch be briquetted. The briquettes could then be introduced through a cupola-like structure atop the feed end of the melter, thus permitting incoming material to remove practically all heat from existing flue production on a continuous flow basis.

By eliminating both the insulating "blanket" of loose batch and reducing wall heat loss area of the regenerators to that of the small cupola-sized preheater, at least 10% of glass melting fuel could be saved.[1]

Refinery Heaters

Traditionally, many refinery (tubular) heaters have been equipped with open hole burners operating with substantial amounts of excess air. Excess air, of course, always represents a fuel waste. With fuels now in scarce supply, excess air can be significantly and safely reduced either by more careful scheduling of off-gases or by use of combustion equipment which, by feedback from a flue analysis, can automatically set efficient air-to-fuel ratios.

Many of the lower quality tubular-heaters are susceptible to additional heat recovery in the top, economizer section. A combustion air recuperation-preheater on a refinery heater is feasible. The temperature range would appear to justify it. If refineries were to use better combustion equipment, a 10% saving should not be difficult to attain.

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[1] LeMay, 1974.

Kilns

Kilns used for firing ceramic products are both batch type (periodic) and continuous. As compared to the larger periodic kilns, the continuous kilns operate far more economically, from both time and fuel standpoints.

Many periodic kilns were designed or built before the advent of refractory insulating bricks and enclosed combustion systems. Those that remain in service can be re-equipped with such insulating bricks and enclosed high quality combustion systems.

High velocity burners added to any kilns can reduce fuel use about 20%.

Other Measures

There are many other areas in which significant potential exists for energy conservation. Due to limitations on time and resources available in this study, these were not investigated in detail. These areas include:

- grain drying
- curing ovens
- finish curing
- accelerated baking and drying
- inorganic chemicals
- organic chemicals

Calculation of Maximum Energy Savings

The baseline projections of the energy consumption in each industry considered are given in Figure III-7. The projections for each industry are in proportion to the projections of total industry energy demand made by the American Gas Association, as submitted to the Federal Energy Administration.

The total industrial energy consumption projection was based on the historical relationship between real personal income in the manufacturing sector and energy consumption. By projecting real personal income, total

BASELINE PROJECTIONS OF ENERGY REQUIREMENTS OF SEVERAL ENERGY INTENSIVE INDUSTRIES

(Trillion BTU)

INDUSTRY	1971	1977[4]	1980[4]	1985[4]	1990[4]
Iron & Steel	5,482[2]	6,578	7,177	8,626	10,083
Aluminum	621[3]	745	813	977	1,142
Copper[5]	67[1]	80	87	105	123
Glass[5]	249[1]	299	326	392	458
Refineries[5]	1,441[1]	1,729	1,886	2,267	2,650
Clay Products[5]	133[1]	160	175	210	245
TOTAL	7,341[1]	8,809	9,610	11,551	13,502

1. Census of Manufactures, 1971.

2. American Iron & Steel Institute Yearbook

3. Derived by multiplying production in 1971 of 4.725 million tons (from U. S. Statistical Abstract, 1972, Table 1124) by the per unit energy requirement of 14,000 Kwh/ton (from Energy Expenditures Associated with the Production and Recycle of Metals, Bravard, Flora, & Portal) (A heat rate of 9,383 BTU/Kwh was used).

4. Projections are proportional to the total industrial energy demand as predicted by the Total Energy Resource Analysis Model as submitted to the Federal Energy Agency by the American Gas Association.

5. 1971 data and projections do not include electricity.

energy can be derived. The projections of manufacturing income are those made by the Department of Commerce and take into account a wide variety of factors such as population, GNP and industrial technology.

The percentage savings realized from each of the measures as described above is shown in Figure III-8. The overall industry percentage savings is calculated using 1971 data as a base. First, the amount of the energy consumption in any particular industry which can use the measure is calculated and then multiplied by the percentage savings to arrive at the amount of energy actually saved.

The 1971 Census of Manufactures data serves as the base year consumption figure, except for aluminum and steel. This data has two major failings. First, it does not include electricity consumption.[1] This, however, is not critical to the analysis because for those industries for which Census of Manufactures data is used, electricity is consumed primarily for lighting and electric drive. These uses are not subject to the energy conservation measures to be considered. (For the aluminum and steel industries, this is not the case so the energy consumption in 1971 for those industries was calculated from production and per unit of production energy consumption rates as described below).

The other major lacking is that the consumption figures are not broken down between boiler steam generation and direct heat uses. This breakdown was considered in Figure III-8 in the column headed "Percentage of Energy Consumption Which Can Use Measure". (Again, in the case of the aluminum and steel industries, this problem was circumvented as described below).

The calculation of the energy consumption in the iron and steel industry is shown in Figure III-9. The amount of energy used in continuous casting was calculated as shown in Figure III-10. The total amount of energy used for steel melting, 131.5 trillion BTUs,

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[1] This data is expected to be available by the end of 1974.

FIGURE III-8

PERCENTAGE ENERGY SAVINGS RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATION MEASURES IN ENERGY INTENSIVE INDUSTRIES

INDUSTRY	CONSERVATION MEASURE	APPLICABLE TO 1971 ENERGY CONSUMPTION OF (10^{12} BTU)	% OF ENERGY WHICH CAN USE MEASURE	% OF ENERGY THUS RECOVERABLE[3]	% OF INDUSTRY CONSUMPTION SAVED	TOTAL INDUSTRY SAVINGS (10^{12} BTU)
IRON & STEEL	1. Open Hearth Converted to BOF	5,482	5.7	84	4.7	258
	2. Continuous Casting	5,482	2.4	90	2.2	118
	TOTAL	5,482	8.1	86	6.9	376
ALUMINUM	Alcoa Process	621	100	30	30	186
COPPER	Chemical Process	67[2]	100	90	90	60
	Vertical Shaft	67[2]	50	50	25	17
	TOTAL[4]	67	-	-	93	62
GLASS	Better Design of Furnace	249[2]	90	10	9	22
REFINERIES	Better Equipment	1,441[2]	75	10	7.5	108
CLAY PRODUCTS	Continuous vs. periodic casting	133[2]	80	50	40	53

[1] American Iron & Steel Institute Yearbook, 1973

[2] Census of Manufactures, 1971

[3] Estimate by R. LeMay in report to MATHEMATICA

[4] Two measures are not additive

FIGURE III-9

CONSUMPTION OF ENERGY BY THE IRON & STEEL INDUSTRY IN 1971

FUEL	CONSUMPTION		HEAT CONTENT (10^{12} BTU)
	PHYSICAL UNITS[1]	CONVERSION FACTORS	
COAL	79.5 million tons	76.2 MMBTU/Ton[2]	2081
COKE	51.7 million tons	24.8 MMBTU/Ton[2]	1282
FUEL OIL	26.4 million bbl	6.29 MMBTU/bbl[2]	166
TAR & PITCH	4.1 million bbl	6.29 MMBTU/bbl[2]	25
LPG	.4 million bbl	4.01 MMBTU/bbl[2]	2
NATURAL GAS	603 BCF	1000 BTU/CF[1]	603
COKE OVEN GAS	873 BCF	550 BTU/CF[2]	480
BLAST FURNACE GAS	4075 BCF	95 BTU/CF[2]	387
ELECTRICITY	48.6 10^9 KWHR	9383 BTU/KWHR[3]	456
TOTAL	-	-	5482

[1] *American Iron and Steel Institute Annual Statistical Report*, 1973

[2] *Interim Report: The Growing Demand for Energy*, April 1971

[3] *Patterns of Energy Consumption in the United States*, Stanford Research Institute, 1972

FIGURE III-10

CALCULATION OF ENERGY REQUIRED FOR STEEL MELTING IN 1971

	FUEL OIL	NATURAL GAS	TOTAL
Per Unit Energy Requirements (KWH/ton)[1]	123.	198	321
Steel Production (10^6 Tons)[2]	120.	120	120
Total Energy Requirement (10^9 KWHR)	14.8	23.8	38.6
Total Energy Requirement (10^{12} BTU)	50.4	81.1	131.5

1. Energy Expenditures Associated with the Production & Recycle of Metals J. C. Bravard, H. B. Flora, Charles Portal, Oak Ridge National Laboratories (ORNL-NSF-EP-24)

2. American Iron & Steel Institute Statistical Yearbook, 1973

is 2.4% of the total energy consumed by the iron and steel industry. This percentage is used in Figure III-8 to arrive at the energy savings resulting from continuous casting. The calculation of the energy requirements by the aluminum industry is given in Figure III-11. The resultant energy savings for each energy intensive industry is given in Figure III-12.

2. Achievable Energy Savings and Impacts

The achievable savings and impacts were not estimated for this measure.

FIGURE III-11

CALCULATION OF ALUMINUM INDUSTRY CONSUMPTION - 1971

PER UNIT REQUIREMENTS[1]	38,500 KWHe/ton
PRODUCTION[2]	4,725 10^3 Tons
ENERGY	181.9 10^9 KWH 620.6 10^{12} BTU

1. Energy Expenditures Association with the Production & Recycle of Metals, J. S. Bravard, H. B. Flora, Charles Portal, 1972.

2. 1972 U. S. Statistical Abstract, Commerce Department.

FIGURE III-12

MAXIMUM ENERGY SAVINGS RESULTING FROM THE IMPLEMENTATION OF INDUSTRIAL ENERGY CONSERVATION MEASURES

(10^{12} BTU)

INDUSTRY	1977	1980	1985	1990
IRON & STEEL				
Energy Consumption	6,578	7,177	8,626	10,083
Percent Savings	6.9	6.9	6.9	6.9
Energy Savings	454	495	595	696
ALUMINUM				
Energy Consumption	745	813	977	1,142
Percent Savings	30	30	30	30
Energy Savings	224	244	293	343
COPPER				
Energy Consumption	80	87	105	123
Percent Savings	93	93	93	93
Energy Savings	74	81	98	114
GLASS				
Energy Consumption	299	326	392	458
Percent Savings	9	9	9	9
Energy Savings	27	29	35	41
REFINERIES				
Energy Consumption	1,729	1,886	2,267	2,650
Percent Savings	7.5	7.5	7.5	7.5
Energy Savings	130	141	170	199
OTHER PRODUCTS				
Energy Consumption	160	175	210	245
Percent Savings	40	40	40	40
Energy Savings	64	70	84	98
TOTAL				
Energy Consumption	9,591	10,464	12,577	14,701
Percent Savings*	10	10	10	10
Energy Savings	973	1,060	1,265	1,491

*Approximate

D. INCREASED RECYCLING OF ENERGY INTENSIVE MATERIALS

1. Introduction

Recycling of materials has several beneficial effects. The most evident ones are the reduction in the usage of raw materials and an alleviation of the problems associated with waste disposal. There is a third area where benefits can be realized: energy savings. The production of manufactured goods require different amounts of energy depending on whether the product is made from virgin material or recycled material.

The following discussion estimates the energy savings resulting from the recycling of steel, aluminum, copper and glass. These materials were analyzed primarily because of the potential energy savings to be realized from recycling.

The analyses were conducted in the following stages:

- estimation of the total amount of the material that is generated as waste,
- determination of the portion of that amount that would be recoverable,
- comparison of the energy thus consumed with the energy that would have been consumed to produce an equal amount from virgin material.

The most significant source of information used in the analysis was a study conducted by EPA's Office of Solid Waste Management Programs.[1] The assumptions and limitations of the EPA study and the use of the results for estimating energy savings are described below.

Total Waste Generation

This area of the analysis was especially difficult, for "...there is no entirely satisfactory data base at present..."[2] In order to arrive at estimates for use in this analysis, several assumptions were made. First, only municipal solid waste was considered. Construction, demolition, industrial, and other possible waste flow sources of material recovery were not considered. There were several reasons for this assumption. There is little data available on the amount of scrap generated by the construction and demolition industries. The same problem exists for municipal wastes, but it was possible to circumvent this deficiency in the area of municipal wastes.[1] All the data on municipal waste was derived by EPA from analyses of industrial material production and product marketing data. This information, in conjunction with estimates of average product lifetimes and material recovery rates, yielded approximate estimates of the levels of municipal wastes. Because of the widely varying product lives associated with large demolition projects, such as buildings and bridges, similar analyses for non-municipal waste was not feasible.

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[1] EPA OSWMP, 1974.

[2] Ibid.

The results of this analysis differ somewhat from measured municipal refuse collection samples. This was due to the following reasons:

- ° The sampling tends not to include the larger refuse items such as appliances and furniture.
- ° This analysis tends to include that portion of the container and packaging material that is disposed of at industrial plant sites through private means.
- ° Sampling studies have not dealt with the full range of the waste generated in this country, namely the residential, commercial, institutional and other post-consumer waste sources.
- ° This analysis does not include any moisture that may have been added as a result of the use of products.

Even with these approximations and assumptions, it is felt that these estimates "can serve as a satisfactory working basis for general analysis and policy formulation purposes at the national level."[2]

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[1] EPA OSWMP, 1974

[2] Ibid.

The other reasons for using only municipal waste is that a significant portion of the non-municipal waste in this country is already being recycled. In particular, 44% of the steel production in 1970 came from recycled scrap.[1]

Amount That Can Be Recycled

It is felt that it would be extremely unrealistic to expect that the entire amount of municipal waste would be recycled. There are two reasons for this that are considered in this analysis. First, a significant portion of the waste generated in the United States is in rural, relatively sparsely populated areas. This would make waste collection extremely expensive. Therefore, for purposes of this analysis, it is assumed that only that waste generated in standard metropolitan statistical areas will be recovered. By assuming that the per capita waste generation is constant throughout the United States, the amount of waste generated in SMSAs can be estimated by multiplying the total national waste generation by the percentage of the population in SMSAs. This percentage is projected to 70 to 74% for the period of the analysis.[2]

The other limitation on the recovery of municipal waste is the efficiency of the recovery apparatus. Due to the mixture of materials in municipal waste, it is expected that the following percentage recoveries would actually be possible:[3]

° Aluminum - 65% to 75%
° Steel - 90%
° Glass - 70%

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[1] Bravard *et al*, 1972.

[2] Frank Smith, 1974.

[3] *Ibid*.

Energy Savings Per Ton of Material Recycled

Based on a survey of the current literature, the energy savings per ton of material recycled were estimated as:

- Aluminum[1] - 200 million BTU/ton
- Steel[1] - 12 million BTU/ton
- Glass[1] - 2.5 million BTU/ton
- Copper[2] - 41.9 million BTU/ton

These estimates were derived by calculating the energy required to produce a ton of material from virgin sources and comparing it with the energy required to produce a ton of materials from recycled material. This analysis did not include the relative costs of transportation, which is an extremely complex issue requiring analysis on a regional basis. For purposes of this analysis, transportation energy requirements were not considered. In essence, this assumption implies that transportation of raw materials is equivalent to transportation of recycled materials. This, of course, may not necessarily be the case.

Results of the Analysis

The results of the analysis, as described above, are summarized in Figure III-13 and are given in more detail in Figures III-14, III-15, III-16 and III-17 for steel, aluminum, copper and glass respectively. It is evident from Figure III-13, that steel and aluminum are by far the most important of the materials in assessing the maximum potential energy savings resulting from the recycling of municipal waste.

Analyses were conducted to establish whether the maximum recycling levels, as discussed earlier, are in fact technologically

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[1] Frank Smith, 1974.

[2] Bravard, *et al*, 1972.

FIGURE III-13

POTENTIAL ENERGY SAVINGS RESULTING FROM RECYCLING OF MUNICIPAL WASTE

(10^{12} BTU)

	1977	1980	1985	1990
Iron and Steel[1]	90	95	107	116
Aluminum[2]	134	164	212	274
Copper[3]	12	13	14	16
Glass[4]	19	20	25	30

1. Figure III-14
2. Figure III-15
3. Figure III-16
4. Figure III-17

FIGURE III-14

POTENTIAL ENERGY SAVINGS RESULTING FROM THE RECYCLING OF IRON AND STEEL FROM MUNICIPAL WASTE

	1972	1975	1977	1980	1985	1990
Total generated (10^3T)	10,710	11,346	11,737	12,217	13,388	14,321
Percentage recoverable for recycling (%)	70	71	71	72	74	75
Total processed (10^3T)	7,500	8,056	8,333	8,796	9,907	10,741
Process Recovery Efficiencies (%)	90	90	90	90	90	90
Amount Recovered (10^3T)	6,750	7,250	7,500	7,917	8,917	9,667
Energy Savings per ton (MMBTU)	12	12	12	12	12	12
Total Energy Savings (10^{12} BTU)	81	87	90	95	107	116

Source: "National Energy Savings from Material Recycling: Some 'Maximum Possible' Estimates for Ferrous Metal, Aluminum, and Glass," Appendix III from "Energy Conservation Through Solid Waste Management", Frank Smith, Office of Solid Waste Management Programs, EPA.

FIGURE III-15

POTENTIAL ENERGY SAVINGS RESULTING FROM THE RECYCLING OF ALUMINUM FROM MUNICIPAL WASTE

	1972	1975	1977	1980	1985	1990
Total generated (10^3T)	901	1,208	1,388	1,627	1,989	2,436
Percentage recoverable for recycling (%)	70	71	71	72	74	75
Total processed (10^3T)	631	858	985	1,171	1,472	1,827
Process Recovery Efficiencies (%)	65	67	68	70	72	75
Amount Recovered (10^3T)	410	575	670	820	1,060	1,370
Energy Savings per ton (MMBTU)	200	200	200	200	200	200
Total Energy Savings (10^{12} BTU)	82	115	134	164	212	274

Source: "National Energy Savings from Material Recycling: Some 'Maximum Possible' Estimates for Ferrous Metal, Aluminum, and Glass," Appendix III from "Energy Conservation Through Solid Waste Management", Frank Smith, Office of Solid Waste Management Programs, EPA.

FIGURE III-16

POTENTIAL ENERGY SAVINGS RESULTING FROM THE RECYCLING OF COPPER FROM MUNICIPAL WASTE

YEAR	Amount in municipal waste (10^3 Tons)	Per Unit Energy Consumption From Raw Material (MMBTU/T)	Recycled (MMBTU/T)	Difference (MMBTU/T)	Energy Savings (10^{12}BTU)
1971	250[1]	46.18[3]	4.28[3]	41.90	10.5
1977	284[2]	46.18[3]	4.28[3]	41.90	11.9
1980	305[2]	46.18[3]	4.28[3]	41.90	12.8
1985	341[2]	46.18[3]	4.28[3]	41.90	14.3
1990	384[2]	46.18[3]	4.28[3]	41.90	16.1

1. Resource Recovery and Source Reduction, Second Report to Congress, EPA, pg. 14
2. Resource Recovery and Source Reduction, Second Report to Congress, EPA, pg. 11. (Growth factor for metallic minerals was used.)
3. Energy Expenditures Associated with the Production and Recycle of Metals, J.C. Bravard, H. B. Flora, Charles Portal, (ORNL-NSF-EP-24).

FIGURE III-17

POTENTIAL ENERGY SAVINGS RESULTING FROM THE RECYCLING OF GLASS FROM MUNICIPAL WASTE

	1972	1975	1977	1980	1985	1990
Total generated (10^6T)	12.1[1]	13.9[2]	14.8[2]	16.1[2]	19.1[2]	22.9[2]
Percentage recoverable for recycling (%)	70	71	71	72	74	75
Total processed (10^6T)	8.5	9.9	10.5	11.6	14.1	17.2
Process Recovery Efficiencies (%)	70	70	70	70	70	70
Amount Recovered (10^6T)	6.0	6.9	7.4	8.1	9.9	12.0
Energy Savings per ton[3] (MMBTU)	2.5	2.5	2.5	2.5	2.5	2.5
Total Energy Savings (10^{12} BTU)	15	17	19	20	25	30

1. *Resource Recovery & Source Reduction*, Second Report to Congress, Office of Solid Waste Management Programs, EPA, March, 1974 pg. 3.
2. *Ibid*, pg. 11, Table 5
3. "National Energy Savings from Material Recycling: Some 'Maximum Possible' Estimates for Ferrous Metal, Aluminum, and Glass," Appendix III from "Energy Conservation Through Solid Waste Management" Frank Smith, Office of Solid Waste Management Programs, EPA.

feasible in the context of the present industries. For aluminum, the process now used can function on 100% scrap. For copper, the amount of copper in municipal waste is estimated to be 250,000 tons maximum.[1] The total production of copper in the United States in 1970 was 3,013,000 tons.[2] Since the recycled copper is less than 10% of the present production, it is assumed that this could be easily absorbed in the production process.

There are technological limits on the percentages of scrap that can be used in the various types of steel-making processes. For the electric furnace, 98% of the input material can be scrap.[3] However, for open hearth and basic oxygen furnace the percentages are 75% and 55% respectively.[3] The fraction of the total steel production that could come from scrap material can be calculated by summing the maximum scrap for each type of furnace. This is shown in Figure III-18 for 1977, 1980, 1985 and 1990. It can be seen from this figure that the maximum amount of iron and steel recoverable from municipal waste, 6.8 million tons, is well within the maximum limits. At the present time, the maximum level of scrap that can be used in the production of steel is 83 million tons, of which 37 million tons presently comes from recycled steel. This leaves 46 million tons which can be produced by increased availability of scrap.

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[1] EPA, Office of Solid Waste Management, March 1974

[2] U. S. Statistical Abstract, Dept. of Commerce, Table 1111.

[3] Darmay, et. al., 1972

FIGURE III-18

CALCULATION OF MAXIMUM CAPACITY OF IRON & STEEL INDUSTRY TO USE SCRAP

(Volumes in millions of tons)

	1971	1977	1980	1985	1990
OPEN HEARTH					
% of Production	30	20[2]	13[2]	7[2]	4[2]
Production	36[1]	28	18	11	7
Maximum Scrap[3]	27	21	14	8	5
BOF					
% of Production	52	57[2]	62[2]	63[2]	62[2]
Production	63[1]	76	86	96	101
Maximum Scrap[3]	35	42	47	53	56
ELECTRIC ARC[2]					
% of Production	18	23[2]	25[2]	30[2]	34[2]
Production	21[1]	30	35	46	55
Maximum Scrap[3]	21	29	34	45	54
TOTAL					
Production[1]	120[1]	134[6]	139[6]	153[6]	163[6]
Maximum Scrap	83	92	95	106	115
SCRAP RECYCLED UNDER PRESENT CONDITIONS[4]	37	40	42	47	51
MAXIMUM SCRAP FOR MUNICIPAL WASTE	46	52	53	59	64
PROJECTED SCRAP FROM MUNICIPAL WASTE[5]	7	8	8	9	10

1. American Iron & Steel Institute Yearbook
2. Extrapolation of historical trends as reported in American Iron & Steel Institute Yearbook.
3. Salvage Markets for Materials in Solid Waste, EPA (For open hearth, 75% of input can be scrap; for BOF, 55% for electric 98%)
4. Assumed to continue at present level of 44% as reported in Energy Expenditures Associated with the Production & Recycle of Metals, Bravard, Flora, & Portal, 1972
5. As derived in Figure III-7

Projected to increase at the same rate as was used for generated scrap in Figure III-7

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

In reaching the energy savings realization possible through this measure, the following implementation schedule was assumed: one percent in 1977, five percent in 1980, 27.5 percent in 1985 and 50 percent in 1990. This realization represents a cumulative 23 percent, or 1,093 trillion BTUs for the 14-year-period.

There were two primary assumptions used in quantifying these reductions:

° Currently there are several pilot resource recovery plants operating or in the development state;[1] more are being planned for operation by 1977. Since it takes approximately two years for these facilities to become operational,[2] these plants represent somewhat less than one percent realization possible in 1977.

° A spokesman from EPA's Solid Waste Management Program estimated conservatively that by 1990, 50 percent of the SMSAs large enough to support a resource recycling system would have one. PMM&Co. assumed a linear increase from the one percent in 1977 to the 50 percent in 1990, since these were the only quantified data.

Several nonquantifiable assumptions were also important factors. PMM&Co. viewed this measure as directed toward the entrepreneur who sets up a recovery and recycling system and who must sell his recycled materials at or below market price for virgin materials. Since raw material prices have been going up and will, in probability, continue upward, the economic feasibility of recycled materials will over time increase, making recovery systems more attractive financially.

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[1] There are pilot plants and demonstration projects existing or planned for Connecticut; New Orleans; Baltimore; San Diego; Ames, Iowa; and Lowell, Massachusetts.

[2] Resource Recovery, June 1974, p. 9.

In the area of possible legislation, there are two Senate bills (S.B. 3549 and 3753) which now propose capital subsidy grants for up to 60 percent of the cost of facilities for energy recovery. Although the chances are slim for passage of either bill this year, aides on the Senate Public Works and Interior Committees feel that the chances are good for similar future legislation which provides some level of capital subsidy for recycling plants.

IMPACTS

Private Consumer

No direct price impacts would be felt by individual consumers as a result of this measure.

Public Sector

This implementation strategy for this measure assumes that materials will be separated out of the municipal waste stream at metropolitan sites and then sold to industry for recycling. This measure is expected to process approximately 10 million tons annually by 1990. Studies[1] have indicated that the net disposal cost associated with plants with a capacity suitable for this measure would be $7.8 billion by 1990. If 60 percent capital subsidy grants are used, the cost would be $3.12 billion to the local recyclers and $4.68 billion to the government.

Imports should be reduced by $150.4 million between 1977 and 1990.

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[1] MRI, 1973.

Quality of Life

Increased recycling of energy intensive materials could have significant effects on the quality of the lives of both producers and consumers, depending on how it is accomplished: if, for example, consumers are required to separate their own waste materials into various types -- e.g. steel, aluminum, glass (source separation) -- before disposing of them, they will have to pay the price of some inconvenience. If producers are required to separate and/or clean waste materials, they will be subject to certain disruptions. If, however, a third party (e.g. a municipal resource recovery center) performs this separation, inconvenience should be eliminated, although there will obviously be an added economic cost.

It is probable that certain lightweight container and structural materials would suffer from recycling due to technological factors; hence, the consumer might have to settle for products that are bulkier or heavier than those made from virgin material. In addition, products which make recycling difficult, -- for example, bimetal cans -- would probably disappear from the market.

In general, however, quality of life, measured in terms of comfort and related factors, should not be significantly affected by efforts aimed at increased recycling.

Scarce Materials/Resources

Increased recycling of energy intensive materials has important scarce materials or resources impacts. In the glassmaking industry for example, there is presently a shortage of soda ash, a vital nonsubstitutable glassmaking ingredient. While it is expected that development of natural soda ash (Trona) facilities in the Western U.S. will eventually alleviate this shortage, the significant positive impact of increased glass recycling on this material/resource problem is clear.

Increased recycling of aluminum has significant impact in terms of overall aluminum availability. While it is generally believed that there is an adequate supply of bauxite ore (the source of aluminum) to satisfy our needs,[1] recent drastic price increases of bauxite by aluminum exporting nations serve to limit our supply of aluminum. It is quite apparent that the more aluminum recycled, the less aluminum that must be purchased abroad at inflated prices.

While we import only 8 percent[2] of our copper, this metal nevertheless is relatively expensive and scarce (although a recent report[3] suggests that there are sufficient U.S. reserves to make the nation self-sufficient at the right price.) Hence, the availability of copper is increased and the price kept down through copper recycling. It should be noted, however, that a significant share of waste copper is presently recycled.

No scarcity of iron and steel exists. Increased recycling of iron and steel, however, can help cut down the amount of imported iron and steel (presently about 30 percent).

Environment

There are two different categories of environmental impacts associated with increased recycling of energy intensive materials. The first category includes reduced air, water, and thermal pollution from basic energy use (including proportionate reduction in electric power generation pollution), as well as those of reduced air, water, thermal, and health effects, characteristic of particular industrial processes of energy intensive material manufacture.

The second category entails reduction of what might be termed end-use pollution; in particular, reduction in the size of solid waste stream which contains many energy intensive materials, as well as reduction of facilities needed to dispose of solid waste, especially landfill sites.

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[1] Final Report, National Commission on Materials Policy, June,1973.

[2] International Economic Report of the President, February 1974.

The complexity of calculations associated with the first category is compounded by the fact that insufficient or low-confidence data exists for most process pollutant effects, including thermal pollution (cf. Hittman Report). As a rough guide, we can say that the impact of this measure on process pollutant reduction corresponds to the net energy savings impact it entails in the industrial sector. Hence, the percentage reduction in process pollutants associated with recycling of energy intensive materials is roughly 0.01% in 1977, 0.05% in 1980, 0.28% in 1985, and 0.5% in 1990. The cumulative process pollutant reduction impact, then, is very small, not equaling 1 percent by 1990.

The end use pollutant impact of this measure is much more significant. In terms of the solid waste stream, recycling of energy intensive materials can result in a waste stream reduction of .160 million tons by 1977, .494 million tons by 1980, 5.18 million tons by 1985, and 9.61 million tons by 1990. The corresponding percentage reductions in the solid waste stream would be .079%, .234%, 2.29% and 4.0%. Demand on landfill would be reduced by .643 million cubic yards in 1977, 1.98 million cubic yards by 1980, 20.8 million cubic yards by 1985, and 38.4 million cubic yards by 1990.

IMPACTS

Figure III-19 shows summary of impacts.

Private Industry

Private industry will be impacted by (1) a new recovering and recycling industry, (2) decreased demand for raw materials and primary finished metals and glass derived from raw materials, and (3) avoidance of power costs to convert raw materials to finished metals and glass.

Preliminary estimates suggest that recycled costs differ from new material costs as follows:

FIGURE III-1[illegible]

RECYCLING IMPACT SUMMARY

	Annual Impact 1977	1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	255	293	354	428	4,668
2. Estimated Feasible	2.6	14.7	97.4	214.0	1,093
B. Impacts (Millions of Dollars)					
1. Private Industry					
Recycling Capital Costs		Not Estimated			
Industry Savings	$3.3m	$19m	$126m	$278m	$1,418m
2. Private Consumer Savings		NOT APPLICABLE			
3. Public Sector					
Government	($11m)	$63m)	($417m)	($63m)	($4,680m)
Balance of Payments 1/	$ 0.2m	$ 1.2m	$ 8.1m	$17.8m	$ 91.0m
4. Employment (Jobs) Primary Material Industries		NOT ESTIMATED			
5. Environment (Percent Reduction)					
Particulates Reduction	.01%	.03%	.20%	.42%	
Solid Waste Reduction	.079%	.234%	2.29%	4.0%	

1/ Does not include steel and copper

	Recycle Cost/Ton[1]	New Cost/Ton	Differential
Steel	$ 43.00	$ 40.50[1]	-$2.50/ton
Aluminum	285.00	540.00[2]	255/ton
Copper	1,080.00	1,740.00[2]	660/ton
Glass	21.02	18.50[1]	- 2.62/ton

Assuming sales would occur at new product cost levels, a net loss would be incurred for recycling of steel and glass. Net gains would be made for recycling of copper and aluminum.

Based upon the estimated level of recovery and the probable recovery mix, the average cost per ton based upon the estimated mix of recycled material would be approximately $27.50/ton less than current prices. The cost saving between 1977 and 1990 would total $1.4 billion.[3]

Employment

Potential job losses could be expected in the steel, iron, aluminum, copper and glass industries. Employment would increase in the manufacturing of municipal resource recovery systems and new employment would also be realized in the personnel required to operate and maintain the systems. Employment data on this new industry are unavailable for an estimate and it is therefore impossible to estimate the resultant aggregate employment impact due to the measure. However, for this analysis, it has been assumed that employment gains would offset employment losses.

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[1] "Second Annual Report to Congress", Environmental Protection Agency.

[2] New York market price, September 1974.

[3] Capital costs have not been included but are estimated at 3.12 billion dollars after subsidies.

E. REDUCED USE OF PACKAGING TO CONSERVE ENERGY INTENSIVE MATERIALS

1. Maximum Energy Savings

BACKGROUND

Packaging has increased tremendously over the past decade with annual per capita consumption jumping from 412 pounds in 1958 to 591 pounds in 1971.[1] In terms of energy consumption, this meant that in 1971, 1.8 quads (5% of the U.S. industrial consumption in that year) were expended in the production of raw materials for packaging. Over 63% of the energy consumed for packaging was utilized in the production of paper. Steel, glass, aluminum and plastic energy consumption ranged between 12% of total energy consumed for steel and 6% for plastic.[2]

In addition to the original purposes of packaging to protect and preserve, other reasons have emerged in recent years, causing a mushrooming effect in use. These include self-servicing of products, consumer attraction to products, and consumer convenience. These product "enhancements" have led to more elaborately and intricately designed packages and to the burgeoning of package sizes and types.

As one might expect, the major increases have occurred in consumer packaging. For example, between 1963 and 1971 consumption of food increased 2.3% by weight on a per capita basis, while tonnage of food packaging increased by an estimated 33.3% per capita and the number of food packages increased by an estimated 38.8% per capita. From 1958 to 1971 aluminum packaging grew 573% per capita. However consumer packaging grew 950% per capita.[3]

CONSERVATION MEASURES

Conservation measures could stem the increasing use of packaging material, thereby reducing the energy consumption related to this category. Three approaches are available for this reduction: increasing the average package size, eliminating over-packaging and reusing packaging.

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[1] EPA, OSWMP, 1974.

[2] Ibid.

[3] Ibid.

- Increasing Average Package Size

The tendency towards smaller, more convenient packages has resulted in increased resource use and energy consumption. Increasing package size could offer significant energy savings. However, there will be repercussions felt by the consumer, the package manufacturer, and the product manufacturer. The consumer will have less choice in the amount he purchases, but larger sized containers should yield a reduction in cost per product unit. Disruption of the packaging industry will also occur. The number of containers required will be reduced and changes will be effected in storage and delivery systems.

- Eliminating Over-Packaging

Packaging has become more multi-layered and a larger selection of materials are being used. More and more products are sold in two packages, one for containment, the other for advertisement. Furthermore, plastics are continually complicating multi-layer applications. Steel and glass, which were combined with paper in the past, are now being combined with plastics.

Reduction in packaging via this approach will also have adverse effects on the package producer, but the effects on consumers will vary somewhat, depending on the actual product and package. The producers of consumer products believe that the package is a necessity to their competitive position in the market. As to whether they can be convinced that industry-wide reduction is in everyone's best interest is very difficult to assess. It can be argued that it should not change their competitive edge since it is the product itself which is the true measure of its competitiveness.

- Reusing Packaging

Within one year of purchase, approximately 90% by weight of

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[1] EPA, Office of Solid Waste Management Program, 1974.

packaging ends up in the trash heap.[1] Packaging trends have supported shorter lifetimes of packaging materials. A reversal of this trend would result in energy savings. The returnable bottle in one type of package which offers significant potential for reuse. (A discussion of returnable bottles is given in Section F). The other type of package which has potential for reuse is the corrugated container. It is believed that corrugated containers could be built such that they could be expected to be used five times. This would mean approximately 80% less energy would be required for this use. However, it is doubtful that the maximum reduction could be approached without an impact on retail outlets, since they would have to assume the major responsibility in coordinating reuse efforts. Unless a relabeling of boxes could be accomplished, the return system would indeed have to be intricate.

APPROACH

It is recognized that it would be an extremely tedious task to project energy savings in each area of reduction. However, a reasonable estimate of a maximum feasible savings can be obtained by comparing historical per capita usage before the great proliferation of packaging to the current trends in per capita usage. This approach was adopted in a previous study for EPA and is the basis of the estimates made in this report.[2]

The 1958 per capita consumption of the major materials utilized in packaging was selected as the goal of the above mentioned programs to reduce energy consumption. (Beverage containers which are considered as a separate measure were excluded from the analysis.) As can be seen from Figure III-20, savings were projected for 1980 by assuming the per capita consumption is reduced to the 1958 levels. Consumption with and without conservation was plotted for the three years given and savings were extrapolated for the years pertinent to the study.

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[1] EPA, OSWMP, 1974.

[2] [illegible]ube, 1974.

FIGURE III-20

ENERGY SAVINGS RESULTING FROM THE DECREASED USE OF PACKAGING MATERIALS (EXCLUDING BEVERAGE CONTAINERS)

(1971 & 1980)

Packaging Material	Total Consumption (thousand tons)[1]			Consumption at 1958 per capita levels (thousand tons)[2]		Potential Material Savings (thousand tons)		Energy Requirement Per ton (thousand Btu's)[3]	Potential Energy Savings (trillion Btu's)	
	1958	1971	1980	1971	1980	1971	1980		1971	1980
Paper	16,552	27,700	39,086	21,137	25,043	6,563	14,043	40,800[4]	267.8	573.0
Glass	5,063	4,900	6,608	6,465	7,660	(1,565)	(1,052)	15,256	(23.9)	(16.0)
Steel	5,340	5,235	6,168	6,819	8,079	(1,584)	(1,911)	29,590	(46.8)	(56.5)
Aluminum	97	212	507	124	147	88	360	196,632	17.3	70.6
Plastics	368	2,900	5,607	470	557	2,430	5,050	36,000	87.5	181.8
Total	27,420	40,947	57,976	35,015	41,486	5,932	16,490		322.5	753.1

(1) Second Report to Congress on Resource Recovery and Source Reduction, U.S., EPA 1974.

(2) Assumes a return to an equivalent 1958 packaging materials mix (i.e. the percentage of each material used in packaging is assumed to be constant). Economic growth, and increased standards of living, is allowed for by increasing total packaging required by a growth factor (the rate of increase in non-durable goods purchased).

(3) Gordian Associates, Energy Consumption for Six Basic Materials Industries, EPA Draft Report.

(4) Approximately 40% of this energy value is derived from the Btu's contained in the raw material (wood), not from purchased fuels.

Source: "National Energy Savings from Source Reduction - Packaging: An Estimate of Possible Impact", Michael Loube, Office of Solid Waste, Environmental Protection Agency.

RESULTS

The results of the extrapolation procedures are given in Figure III-21. The total energy savings range from 568 trillion BTUs in 1977 to 1289 trillion BTUs in 1990. The projections assumed a trended increase in per capita usage of glass and steel over the present rates. Paper, aluminum, and plastics show resultant energy savings with paper providing the major share as might be expected based on its widespread use in packaging.

Refinement of these projections would be most beneficial. In particular, varying the material mix from the 1958 values would add a greater depth of realism to the projections, since not all changes in packaging since 1958 have been negative. For instance, plastic has been substituted for glass in various nonreturnable containers adding an extra degree of safety. Household bleach, which in 1958 was bottled in glass, is one such example. Since some plastic bottles are considerably lighter than glass, it may be possible that a slight reduction in energy consumption may accru from such applications. Tradeoffs such as these should be investigated and appropriate adjustments be made to the projections.

It would also be valuable to investigate the types of packaging which have increased the most in recent years and evaluate the increase energy consumption versus the social benefits accruing from the packaging.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

An EPA scenario was used to arrive at a reduction in the maximum possible energy savings. A spokesman from EPA's Office of Solid Waste Management Programs was quoted as saying that the agency expected industry to have a program of voluntary cooperation in reduction of packaging by 1985. However, it is not presently anticipated that the program will be successful. If the program fails, federal legislation would be developed and implemented. For purposes of this analysis, it has been assumed that the voluntary programs will not succeed. Feasible energy savings estimates are based on legislation which would be enacted by 1985 and which would call for phased compliance with 100 percent attainment by 1990.

FIGURE III-21

POTENTIAL ENERGY SAVINGS FROM REDUCED USE OF PACKAGING MATERIALS (EXCLUDING BEVERAGE CONTAINERS)

(10^{12} BTUs)

PACKAGING MATERIAL	1977	1980	1985	1990
Paper	453.0	573.0	783.0	930.0
Glass[1]	(19.8)	(16.0)	(11.4)	(7.6)
Steel	(53.9)	(56.5)	(59.9)	(62.9)
Aluminum	39.3	70.8	106.2	151.0
Plastics	149	[illegible]	228.6	278.1
TOTAL	568.0	75[illegible]	1046.5	1288.6

Source: "National Energy Savings from Source Reduction in Packaging: Estimate of Possible Impact", Michael Loube, Office of Solid Waste, Environmental Protection Agency.

[1] The savings for glass decrease over time because the baseline projection of packaging material requirements total assumed that the glass share of the packaging material increased. Thus, when applying the 1958 glass market shares for all years, which is greater then the projected glass shares, the difference between the market shares decreased resulting in decreasing energy savings.

These percentage reductions were based primarily on nonquantitative logical assumptions. According to the Packaging Institute, Inc.,[1] there would be tremendous industry resistance to reduction in packaging. Packaging is an extremely competitive area; it represents a basic marketing and advertising strategy and a means of differentiating brands, as well as a product container. Individual companies are extremely reluctant to alter their strategies by reducing either the many different product sizes which appeal to various market segments or by changing the mix of packaging materials currently in use. In recent years, the mix has tended to include a higher proportion of plastics and aluminum--energy costly materials.[2]

Another factor is that the industry as a whole, apparently does not believe that it is exceeding packaging needs.[3] Therefore, while voluntary cooperation was mentioned as an alternative, industry representatives were not optimistic about its success. The EPA scenario apparently also forecast a lack of success with voluntary measures.

It was assumed that a binary situation would exist with regard to eventual federal legislation and guidelines. Given the strength of industry opposition, it would probably be very difficult to enact legislation forcing industry to reduce packaging.[4] However, if such guidelines were enacted as EPA expected, the energy savings were assumed to be 100 percent of the maximum possible.

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[1] An association of manufacturers and packagers.

[2] Packaging Institute, Inc.

[3] Statement from the President of Packaging Institute, Inc.; Assistant Director of Public Information, General Foods; staff of Office of Packaging Technology, Food & Drug Administration.

[4] Staff of Office of Packaging Technology, FDA.

Other nonquantifiable feasibility factors relevant to this measure include considerable inconvenience to the consumer, who would have to buy larger quantities of goods, perhaps less easy to store and more susceptible to spoilage, and to the retail merchant, who has come to use packaging to replace the salesclerk who measured and weighed the goods. Certain types of containers, such as aerosol spray cans, might be removed from the market. Since a return to the per capita packaging consumption and mix of 1958[1] would include a much higher percentage of returnable glass bottles, facilities for storing, washing and hauling them would also have to be built.

IMPACTS

Private Consumer

Assuming a direct correspondence between reduced packaging cost (sales loss) and consumer prices, consumer net savings would be approximately $2.6 billion in 1990. However, package changes will impact consumers in terms of fewer small quantity packages, returnable bottles and other basic changes in product availability. Each major shift could potentially impact final consumer product cost in either a positive or negative manner.

In addition, it is not realistic to assume that reduced product packaging costs would be fully passed on to the consumer. Therefore, the simplistic assumption used for impact evaluation should not be considered as a realistic projection of reduced consumer costs.

There would, however, be some reduced solid waste disposal costs as a result of this measure which might accrue to the private consumer.

Public Sector

If, in fact, consumer costs were reduced, state and local governments could lose retail sales taxes levied against impacted retail products. Assuming a nationwide average sales tax of 5%, the public revenue cost could be $462 million. However, because tax levies vary substantially by area, and products subject to tax vary substantially by area, the above estimate cannot be considered a realistic tax estimate.

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[1] Assumption used by MATHEMATICA to estimate maximum potential energy savings.

Finally, if this measure were implemented, the federal government could be required to administer a package conservation program. While it is not possible to estimate costs of program administration, it should be recognized that such costs could be quite substantial.

Avoided oil imports are estimated at $191 million between 1985 and 1990.

Quality of Life

There is a great deal of conflicting opinion as to how packaging, or the lack of it, influences quality of life. The fact remains however, that excess packaging practices do exist. Such practices result in two basic types of excess packaging:

- items which could be sold in bulk are packaged individually (e.g., slices of cheese);
- items which warrant individual packaging are wrapped in an excessive amount of materials (e.g. bars of soap enclosed in paper and foil layers).

It is clear that reduced packaging in the latter category will not pose any inconvenience for the customer; e.g. eliminating the plastic or cellophane wrapper that does not affect shelf life will, in no way, present a quality of life problem to the consumer. In fact, the convenience and comfort of the consumer is actually increased by reducing the size of the solid waste stream.

Packaging reduction in the first category may or may not pose problems of inconvenience. Eliminating cellophane wrapping from a naturally protected item like a coconut would pose no problem. Likewise, buying ten nails out of a bin would pose no more transporting problem than buying ten wrapped in a composite cardboard/plastic container. On the other hand, buying milk from a bulk source would prove both inconvenient and possibly unhealthy, and purchasing washing detergent in bulk would be very inconvenient for many people.

In short, there are some substantive problems of convenience and transport which could arise out of indiscriminate reductions in packaging.

Scarce Materials or Resources

Reduced use of packaging can reduce scarcity situations in both the organic and materials sectors. A significant fraction of packaging material is organic, in particular, plastic, paper, and cellophane. Reduction in plastic packaging material is important in terms of reducing petrochemical, and, therefore, oil demand. Reducing paper and cellulose use not only can minimize possible shortages of these materials, but can minimize forest destruction.

Reduction of use of metals in packgaging, particularly, aluminum foil, can supplement recycling efforts, and thus further contribute to increased metal availability.

Environment

The particular nature of this measure dictates that the substantive impacts it will have will occur only in 1990. As detailed in the environmental impacts discussion of the energy intensive materials recycling measure, reduced packaging entails pollutant reduction in processing, as well as end-use categories. As a guide to process pollutant reduction, energy savings entailed by this measure can be compared to total energy consumption in the industrial sector. By 1990, a reduction of approximately 2.2 percent of industrial energy consumption is possible through implementation of the reduced packaging measure. This indicates that a significant contribution to industrial process pollutant reduction can be achieved through this measure.

In terms of solid waste pollution reduction, packaging reduction brings about a cumulative solid waste stream reduction of 23.2 million tons, or 9.5 percent of the total solid waste stream. This reduction entails a reduced demand on landfill disposal facilities of 93 million cubic yards.

Litter, a very visible form of pollution due in part to packaging discards, might also be reduced somewhat through implementation of the reduced packaging measure. There are, however, insufficient data to quantify the degree of this reduction.

Private Industry

The maximum energy savings associated with this measure would be due to a return to 1958 per capita consumption of paper, glass, steel, aluminum and plastics. Applying the 1958 packaging materials mix, paper, aluminum and plastic sales would decrease while glass and steel sales would increase. The estimated product mix change would be as follows:

Industry	% of Total Production for packaging 1971[2]	Sales for packaging 1970[3]	Reduction to materials mix in use in 1958[4]	Estimated new packaging sales level
Glass	74.5%	$3,695 m.	1.32	$4,879 m.
Steel	8.3	$2,126 m.	1.30	$2,763 m.
Aluminium	14.1	$ 710 m.	.59	$ 419 m.
Plastics	29.0	$1,276 m.	.16	$ 204 m.
Paper	47.2	$9,743 m.	.76	$7,405 m.
		$17,550 m.		$15,670 m.

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[2] "Second Annual Report to Congress on Solid Waste Management", EPA.

[3] IRS published industry earnings and U.S. Industrial Outlook, 1971.

[4] "Natural Energy Savings from Source Reduction Packaging: An Estimate of Possible Impact", Michael Lorbe.

If full change was in force in 1971, the net loss in packaging material sales would have been approximately $1.9 billion. Projecting the impact to the year 2000, based upon probable 1990 consumption levels and a 1958 package materials mix, the 1990 annual net sales loss would be $2.6 billion. Assuming straight line implementation growth between 1985 and 1990, the cumulative net sales loss would be approximately $7.9 billion.

Employment

Employment losses would result from decreased package material sales. The package material industry would be impacted by a net loss of approximately 62,691 jobs by 1990. This job loss may be partially compensated for by new jobs resulting from increased labor requirements in distribution and retailing. Data were not available from which to estimate these latter impacts.

A summary of impacts is shown in Figure III-22.

FIGURE III-[illegible]

PACKAGING IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	387	524	734	917	9,095
2. Estimated Feasible	0	0	0	917	2,293
B. Impacts (Millions of Dollars)					
1. Private Industry Industry Net Sales Loss	0	0	0	($2,638m)	($7,900m)
2. Private Consumer Savings	0	0	0	$2,638m	$7,900m
3. Public Sector					
Government	0	0	0		($395m)
Balance of Payments	0	0	0	$ 76m	$191m
4. Employment (Jobs) Packaging Industry	0	0	0	(14,390)	(62,691)
5. Environment (Percent Reduction) Solid Waste Stream	0	0	0	9.5%	

F. INCREASED USE OF RETURNABLE BOTTLES

1. Maximum Energy Savings

INTRODUCTION

There has been a significant trend in the increasing use on non-returnable, throw-away bottles. From 1959 to 1969, the average number of fillings per container decreased from 3.7 to 1.8.[1] There are three basic reasons for this: Consumers' preference, retailers' reluctance to handle bottles, and the packaging industry's desire to maintain increases in production levels. In the State of Oregon, these tendencies have been overcome through the use of legislation forbidding the use of non-returnable bottles and cans.[2]

The objective of this analysis was to determine the maximum attainable energy savings resulting from the substitution of non-returnable containers with returnable beverage containers.

The approach chosen for this analysis was to first project the use of each type of beverage container. By multiplying this baseline forecast of container use by the energy required for the use of each type of container, the total energy requirements by the soda and beer bottling industries was calculated.

In order to estimate the maximum energy savings, this baseline energy requirement was compared against the energy required to provide the same number of containers by the least energy intensive container, the returnable bottle.

BASELINE CONSUMPTION PROJECTION

Figure III-23 shows the baseline projections for beer and soda consumption. The 1976 projection was based on a report made for the EPA by the Research Triangle Institute.[3] This report

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[1] EPA, OSWMP, March 1974.

[2] Eileen Claussen, 1973.

[3] Bingham, Mulligan, 1971.

FIGURE III-[illegible]

BASELINE PROJECTIONS OF THE U.S. SODA & BEER CONSUMPTION

YEAR	SODA (Billions of 192 oz. cases)	BEER (Billions of Gallons)
1969[1]	2.91	3.57
1976[1]	4.22	4.51
1977[2]	4.46	4.66
1980[2]	5.28	5.16
1985[2]	6.97	6.10
1990[2]	9.22	7.22

1. The Beverage Container Problem (EPA-R2-72-059), Taylor H. Bingham & Paul F. Mulligan, Office of Research and Monitoring, EPA, September 1972.

2. Extrapolation of projections made in The Beverage Container Problem.

considered a variety of factors, such as income and population by age group, marketing techniques and packaging practices, to arrive at projections of soft drink and beer consumption. The one most important factor used in this projection was per capita consumption trends. For soda, annual per capita consumption has increased 88% from 1955 to 1969 (from 1,464 oz. to 2,752 oz.) while beer has increased at a slower rate of 10% (2,044 oz. to 2,244 oz.).

ENERGY SAVINGS

The total energy requirements were estimated by multiplying the level of consumption by the per unit energy requirements of each type of container. The results of this analysis are shown in Figures III-24 and III-25.

A good source of data on the energy requirements for each type of container is contained in a recent study done for the EPA Office of Solid Waste Management Programs. Unfortunately, the only data that has been publicly released from that study has been published in the Second Report to Congress on Resource Recovery and Source Reduction.[1]

In order to estimate the maximum potential energy savings, it is assumed that all beverage containers will be returnable and the average number of trips will be ten. The maximum potential energy savings are then calculated as the difference between the baseline energy requirements and the energy requirements assuming all beverage containers to be reusable. The calculated energy savings are shown in Figure III-25.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

The non-returnable beverage container measure represents an essentially binary situation in which there would be 100 percent realization if and when the necessary legislation were to be enacted, and zero realization without the legislation. Therefore, based on an estimate by an EPA spokesman[2] that a nonreturnable

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[1] EPA, OSWMP, 1974.

[2] Spokesman from the Office of Solid Waste Disposal Program EPA,1974.

MAXIMUM POTENTIAL ENERGY SAVINGS RESULTING FROM THE USE OF RETURNABLE BEER BOTTLES

	1976	1977	1980	1985	1990
Consumption (10^9 Gal.)	4.51[3]	4.66[4]	5.16[4]	6.10[4]	7.22[4]
By type of container[1]					
Bottles					
Returnables (10^9 Gal)	1.24	1.28	1.42	1.68	1.98
Non-returnables (10^9 Gal)	1.17	1.21	1.34	1.58	1.87
Total (10^9 Gal)	2.41	2.49	2.76	3.26	3.86
Cans (10^9 Gal)	2.10	2.17	2.40	2.84	3.36
Energy Consumption[2]					
Bottles					
Returnables (10^{12} BTU)	29.8	30.8	34.1	40.3	47.7
Non-returnables (10^{12} BTU)	84.0	86.9	96.1	113.7	134.4
Total (10^{12} BTU)	113.8	117.7	130.2	154.0	182.1
Cans (10^{12} BTU)	119.7	123.8	136.9	162.0	191.5
Total (10^{12} BTU)	233.5	241.5	267.2	315.9	373.6
Energy Consumption Assuming All Returnable (10^{12} BTU)	108.4	112.0	124.0	146.6	173.6
Energy Savings (10^{12} BTU)	125.1	129.5	143.2	169.3	200.1

1. Based on percentage breakdown for 1969 as reported in The Beverage Container Problem, (EPA-R2-72-059).

2. Energy consumption rates based on data for 12 oz. beer containers from Resource Recovery and Source Reduction, Second Report to Congress, EPA, pg. 81

3. The Beverage Container Problem, op. cit. page 134.

4. Extrapolation of projections made in The Beverage Container Problem, op. cit.

FIGURE III-25

MAXIMUM POTENTIAL ENERGY SAVINGS RESULTING FROM THE USE OF RETURNABLE SOFT DRINK BOTTLES

	1976[3]	1977[4]	1980[4]	1985[4]	1990[4]
Consumption (millions of 192 oz. cases)	4,218	4,461	5,277	6,972	9,216
By type of containers[1]:					
Bottles					
Returnable (millions of 12q cans)	1,265	1,338	1,583	2,091	2,764
Non-returnables (millions of 12q cans)	970	1,026	1,213	1,603	2,119
Total (millions of 12q cans)	2,235	2,364	2,796	3,694	4,883
Cans (millions of 12q cans)	1,987	2,101	2,486	3,285	4,342
Energy Consumption (10^{12} BTU)					
Bottles (10^{12} BTU)					
Returnable (10^{12} BTU)	45.5	48.1	56.9	75.2	99.4
Non-returnable (10^{12} BTU)	104.8	110.8	131.1	173.2	229.0
Total (10^{12} BTU)	150.3	149.0	188.0	248.4	328.4
Cans (10^{12} BTU)	169.9	179.7	212.5	280.8	371.2
Total (10^{12} BTU)	320.2	338.6	400.6	529.3	699.6
Energy Consumption Assuming All Returnable (10^{12} BTU)	151.8	160.5	189.9	250.9	331.7
Energy Savings (10^{12} BTU)	168.4	178.1	210.7	278.4	367.9

1. Based on percentage breakdown for 1969 as reported in The Beverage Container Problem (EPA-R2-72-059).

2. Energy consumption rates based on data for 12 oz. beer containers from Resource Recovery and Source Reduction, Second Report to Congress, EPA, page 81. (to be replaced by rates for soda when obtained)

3. The Beverage Container Problem, op.cit. pg. 124.

4. Extrapolation of projections made in The Beverage Container Problem, op.cit.

beverage container law will be enacted no later than 1985. PMM&Co. assumed zero realization until then, with 100 percent of the maximum energy savings thereafter.

There are several reasons why it could not be assumed that the measure could be implemented in 1976. Any such bill in Congress would encounter great opposition from the aluminum and can industry, beverage manufacturers, large grocery chains (who would have the bulk of returnable storage problems), and others. Labor unions, for example, have been opposed because the enactment of such a law would reduce jobs in certain industries, especially lower-income jobs.[1] Consumers would be inconvenienced by having to store and then return empty bottles.

There are other problems as well: nonreturnable containers allow manufacturers to produce in a few centralized plants to serve distant markets. New facilities would have to be built. In addition, a large percentage of container handling equipment might become obsolete during the transition of refillable containers.[2]

The existing legal precedent is the Oregon "bottle bill" enacted in 1971. Many other states have been unsuccessful in attempts to eliminate nonreturnable beverage containers; Vermont enacted such a law but repealed it. There is a Senate bill (S. 2062) which proposes to stop the introduction of nonreturnables into interstate commerce. However, although in favor of the bill's premise, EPA does not support its enactment because of the lack of a phase-in period and a confusing provision distinguishing between inter- and intra-state shipments.[3]

For these reasons, PMM&Co. in this analysis accepted the EPA estimate of legislation delayed until 1985, if enacted at all.

A summary of the impacts is shown in Figure III-26.

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[1] Testimony from the Oregon Court of Appeals brief on the Oregon "Bottle Law," 1973.

[2] Ibid.

[3] Statement of John Quarles, Deputy Administrator of EPA, before Subcommittee on the Environment, Senate Commerce Committee, May 1974, p. 13-14.

[illegible]

NONRETURNABLES IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. **Energy Savings** (BTUs x 10^{12})					
1. Maximum	307.6	353.9	447.7	568.0	5,866
2. Estimated Feasible	0	0	447.7	568.0	3,048
B. **Impacts** (Millions of Dollars)					
1. Private Industry					
Industry Savings			$534m	$631m	$3,600m
2. Private Consumer					
Savings			$1,875m	$2,357m	$12,700
3. Public Sector					
Government			$134m	$168 m	$ 899
Balance of Payments			$ 37m	$ 47m	$ 257m
4. Employment (Jobs)					
Industry			0	0	0
5. Environment (Percent Reduction)					
Solid Waste Reduction			6.1%	7.4%	

Private Consumer

Hugh Folk at the University of Illinois' Center for Advanced Computation has estimated that a bottle bill could save Illinois consumers $71 million annually.[1] Projecting the figure to the entire nation based on population would suggest a savings of $10.5 billion.

Public Sector

Studies have shown that beverage container litter cost the nation $93 million per year in clean-up costs.[2] Projecting to 1990 a ban on non-returnables would save local governments $899 million in clean-up costs assuming a 65 percent reduction in beverage container litter.

Balance of payments savings from reduced energy imports would be $275 million.

Quality of Life

The one substantive case study of elimination of non-returnable beverage containers is that of the State of Oregon's "bottle bill", which has been in effect for nearly two years. In the several studies of the "bottle bill's" effects made by the Oregon Environmental Council,[3] there has been no indication of significant quality of life impacts, although this aspect has not been treated in depth.

Many national beverage producers report significant inconveniences, translated into increased costs, posed by the necessity of hauling empty beverage containers hundreds of miles to processing plants--even though beverage delivery trucks go back empty to plants now. Likewise, retailers have had to take on the burden of processing returned bottles, as well as transporting of empty bottles. Nevertheless, eliminating nonreturnables appears to be posing no important quality of life problems in Oregon. The past president of the Oregon Environmental Council summed up his group's findings in regard to the "bottle bill" in these words: "to state the outcome simply, it's working."[1]

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[1] Hanna, B. M. System Energy and Recycling: A study of the Beverage Industry, CAC Doc. No. 23, Center for Advanced Computation, University of Illinois, January 5, 1972.

[2] The Beverage Container Problem, (EPA-R2-72-059).

[3] See, for Example, "Oregon's 'Bottle Bill' - One Year Later," Oregon Environmental Council, Portland, Oregon, October 4, 1973.

Scarce Materials/Resources

Eliminating nonreturnable beverage containers can have a very important resource conservation effect, particularly if this measure were coupled with increased recycling and reduced packaging measures.

In terms of materials scarcity, the most important impact of this measure would be in the aluminum and glass sectors. Aluminum is becoming disproportionately scarce as its price increases. The shortage of soda ash in the glass making industry is putting excess pressure on glass production facilites. The extent to which the glass industry can meet added demand resulting from implementation of this measure is uncertain. would increase.

Environment

As in the recycling and packaging reduction measures, a processing pollutant reduction guide can be obtained by computing the percent reduction in industrial energy consumption entailed by banning nonreturnable beverage containers. While no reduction is feasible in 1977 and 1980, an approximate 1.5 percent reduction in total industrial energy consumption in 1985 is possible. Hence, banning nonreturnable containers can make an important contribution to reducing industrial processing pollutants.

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[1] Testimony of the Oregon Environmental Council before U.S. Senate Commerce Committee, May 6, 1974.

The major environmental impact entailed in this measure is in its contribution to reducing solid waste and litter. By 1985, 15.1 million tons, or 6.1 percent of the solid waste stream could be eliminated through the measure. A reduced landfill demand of 60.4 million cubic yards would be entailed. By 1990, 19.3 million tons of containers (7.4 percent of all solid wastes) could be removed from the solid waste stream, with an associated landfill reduction of 70.2 million cubic yards.

The Oregon "bottle bill" has demonstrated that banning nonreturnable containers can have a significant and dramatic effect in litter reduction. Preliminary results show that container litter has been reduced by 65%[1] through banning nonreturnable containers.

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[1] Second Report to Congress, "Resource REcovery and Source Reduction," U.S. EPA, 1974.

Private Industry

A major impact of the elimination of non-returnable beverage containers would be the elimination of the metal beverage container industry, which has been estimated at $1.5 billion per year.[1] However, the loss of this industry would be somewhat offset by increases in the glass bottle industry and by increases in the industry producing bottle processing equipment(e.g., washers, sterilizers).

Brewers and soft drink bottlers, as well as others, would gain from the overall decrease in container costs. Oregon's experience has revealed that profits to all business sectors in the state directly affected by its bottle bill increased $3.9[2] million in the first year of the law. Using Oregon's results for national projections indicates that approximately $3.6 billion in extra profits could be realized by brewers, soft drink bottles and other related industries by 1990 (based on annual sales). Such an estimate must be prefaced, however, by the caveat that some brewers were able to shift their sales of non-returnables to other states in the West. If the ban on non-returnables were adopted nationwide, such product shifts would not be feasible.

Employment

If the $1.5 billion per year beverage container industry is eliminated as EPA suggests (see above), 30,327 jobs would be eliminated. However, many of these workers would probably just be dislocated in the sense that they would be hired by the glass bottling industry, brewers, and soft drink bottlers, where more than 30,000 new jobs may be created. This is because bottles are generally more labor intensive than cans.[3] New employment in the glass and/or beverage industry was not estimated. However, since the expected employment increase should be at least equal to the employment decrease, a net impact of zero has been assumed.

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[1] "Second Report to Congress." Op. cit.

[2] The Economic Impact of Oregon's "Bottle Bill." C. Gudger and J. Bailes, Oregon State University, March 1974.

[3] Gudger and Bailes report in their Oregon study an instance reported by a brewing company where 2,000 cases per hour are filled on a canning line operated by four men and 1,200 cases per hour being filled on a bottling line operated by 13 men.

G. TOTAL ENERGY SYSTEMS

1. Maximum Energy Savings

Total energy systems are on-site electricity generators which are designed so as to allow for the usage of the waste heat generated. In most instances, the heat generated by central powerplants is not used. Since the amount of waste heat is approximately twice the electricity generated in terms of BTU content, potential energy savings are significant.

It is extremely difficult to estimate what portion of the industrial market can utilize total energy systems. Not only must there be a certain minimum amount of electricity consumption, there must be a matching load for the waste heat that is recovered. For purposes of this analysis, it is assumed that those plants which now generate electricity on-site can utilize total energy systems. Although this somewhat understates the full potential of total energy systems, it is felt this is the most realistic assumption in light of the data limitations.

Figure III-27 shows the historical and projected levels of on-site power generation.[1] The basic assumptions used in estimating the maximum energy recoverable from on-site power generation are that 50% of the waste heat is recoverable[2] and that all of the recoverable waste heat can be utilized. While the latter assumption is not valid for the residential sectors, it was felt that because of the greater control of industrial processes and higher regularity of demand, all recoverable energy could be utilized.

Based on historic data, the projections shown in Figure III-27 were prepared. Using the above assumptions, recovered energy was then computed as equal to the BTU equivalent of the electricity generated.

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[1] Electricity generated on-site which is sold to outside customers is not included. However, it is felt that this is a small portion of the total electricity generated on-site.

[2] Dept. of Housing & Urban Development, July, 1973.

FIGURE III-27

BASELINE PROJECTIONS OF MAXIMUM ENERGY SAVED RESULTING FROM THE USE OF TOTAL ENERGY SYSTEMS BY THE INDUSTRIAL SECTOR

YEAR	ENERGY SAVED (10^9 KWH)	ENERGY SAVED (BTUx10^{12})
1960	70.0[1]	238.9
1965	80.5[1]	274.7
1970	81.4[1]	277.7
1975	105.3[2]	359.4
1977	112.2[2]	382.9
1980	122.6[2]	418.4
1985	148.0[2]	505.1
1990	173.4[2]	591.8

1. Equal to electricity "generated less sold" as reported in the Annual Survey of Manufactures.

2. Projected in proportion to projections of total industrial energy demand as made in Total Energy Resource Analysis Model as submitted to the Federal Energy Administration.

Note: The level of usage of total energy systems is assumed to be the amount of on-site electrical generation in the industrial sector. The energy saved, or recovered, is equal to the amount of electricity generated by the total energy systems.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

The estimates of maximum energy savings possible through the promotion of total energy systems (TES) in industrial plants was reduced to one percent in 1977, 5 percent in 1980, 15 percent in 1985, and 25 percent in 1990. The cumulative (1977-1990) savings realization would be approximately 13 percent of the maximum possible, or 851 Trillion BTUs.

The following quantifiable factors were used in reducing estimates of maximum savings:

° As discussed in the commercial sector, a spokesman involved in HUD's Total Energy System program[1] said that in 1974 there are currently at least 600 commercial and industrial buildings and plants operating under total energy systems. Therefore, with the measure implemented in 1976, there would be only a very small proportion of plants operating under TES by 1977.

° A maximum of 25 percent implementation within the industry sector by 1990 was estimated by Eugene Gore, an expert in the total energy field,[2] based on his technological and logistical feasibility studies. The reasons for this relatively low level of implementation are discussed below.

However, there are other nonquantifiable factors which might mitigate against a full 25 percent implementation of the measure. Adoption of the total energy system concept would be more difficult for the industrial sector than for commercial buildings. While TES and selective energy systems are technologically feasible for many highrise commercial buildings, industries with low thermal demand (e.g.,the aluminum industry) cannot use TES effectively. Each type of industry and each basic process within that industry would have to be examined to determine whether thermal demand was high enough to support a total energy system - a complicated and prohibitive problem, according to the HUD spokesman.

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[1] Utilities Systems Research, Office of Policy Development and Research, U.S. Department of Housing and Urban Development.

[2] Eugene Gore, S.W. Brown Associates, consulting engineers, New York City.

Because of these difficulties, the economic attractiveness of total energy would be essential to even a 25 percent ultimate implementation of the measure. The HUD spokesman and Gore based their opinions of the measure's feasibility on at least a 7 percent tax credit which could apply to capital investments in TES equipment. Under current IRS law, equipment would be considered part of the structural components of a building, and the federal tax law would have to be changed to cover energy conserving systems. The IRS would also have to develop appropriate mechanisms to ensure that the credit was used properly.

The attitudinal problems cited in the TES commercial measure, with the reluctance of savings and loan associations to finance TES, would not really apply to the industrial sector because most plants are financed by means other than commercial banks. However, the opposition of the utility companies would still present problems, since they have challenged the builders and prospective builders of total energy systems in more than 450 court cases. (Utilities see TES as infringing on their right to produce electric power). As Gore suggested, federal intervention might be necessary to induce cooperation from the utilities. HUD has begun a five-year education campaign to help utility companies, as well as other skeptical institutions, learn about the energy conservation advantages of TES.

IMPACTS

A summary of impacts is shown in Figure III-28.

FIGURE III-28

TOTAL ENERGY SYSTEMS IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	382.9	418.4	505.1	591.8	6,654
2. Estimated Feasible	3.8	20.9	25.8	148.0	851
B. Impacts (Millions of Dollars)					
1. Private Industry					
Industry Savings	$10.4m	$56m	$203m	$397m	$2,279m
Annualized Industry Conversion Cost	($ 0.1m)	($ 2.4m)	($ 8.7m)	($ 16.5m)	($8,103.6m)
2. Private Consumer		NOT ESTIMATED			
3. Public Sector					
Government	0	($0.1m)	($0.3m	($0.9m)	($4.4m)
Balance of Payments	$0.3m	$1.7m	$2.1m	$ 12.3m	$ 71.0m
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction) SO_2 **Emissions**	.006%	.03%	.03%	.20%	

Private Consumer

While industry operating costs would be substantially impacted, no passed-on consumer savings have been estimated.

Public Sector

A 7% investment tax credit or approximately $4.4 million between 1977 and 1990 would be lost tax revenues to the federal government. Reduced energy consumption from total energy systems will save the U.S. approximately $71 million in imports of oil by 1990.

Quality of Life

Quality of life impacts should be minimal for implementation of total energy systems in industrial processes, since the measure merely fosters more efficient use of energy sources.

Scarce Materials/Resources

There are no major scarce materials/resources impacts associated with total energy system use in the industrial sector.

Environment

In terms of environmental impact, the increase implementation of total energy systems in industrial processes means, principally, that: a) there will be a decrease in pollutants from electrical generating sources, since total energy systems generate electricity roughly twice as efficiently as commercial facilities; and b) there will be a decrease in pollutants from basic industrial energy use, since total energy systems make more efficient use of waste heat.

Power generation impacts include primary air pollution effects of fossil fuel electric power plants, as well as radiation and thermal effects from nuclear powered plants. Industrial impacts include air pollution effects from fossil fuel consumption in industry, as well as associated thermal pollution. Thermal pollution effects are particularly difficult to quantify as insufficient data exists to correlate quantiatively thermal pollution with industrial energy consumption.

Sulfur dioxide reduction impact is a guide to the pollution reduction impact of total energy systems, since SO_2 is the major pollutant from fossil fuel conbustion. In 1977, this measure would produce a sulfur dioxide emission reduction of about 0.006% of total emissions of this pollutant. The equivalent reductions in SO_2 emissions for the other years are as follows:

1980: 0.03%
1985: 0.03%
1990: 0.20%

The overall pollutant reduction impact of this measure is realtively small.

Private Industry

The industry impact estimates assume that the usage level of total energy systems is the amount of on-site electrical generation in the industrial sector. Capital costs would then be the cost of converting or building on-site electrical generation systems.

Total energy system capital costs for new structures are estimated at 10 percent of the industrial building cost.[1] Retrofit installation costs have been estimated at \$20/kw.[2] For purposes of this study, \$20/kw was the base value for estimation of conversion to total energy systems. Operating costs have been estimated at 50 percent of nontotal energy system costs. For the purpose of this analysis, the operating savings are assumed to be equal to avoided fossil fuel purchases.

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[1] MATHEMATICA

[2] Economic Evaluation of Total Energy Technical Report, Department of Housing and Urban Development, Contract No. H-1776, July 1973. Installment cost only, capital equipment cost not included.

[3] This factor does not account for all equipment capital cost. A complete capital cost factor was not available for the study.

At $20/kw and assuming an average system utilization of 66.7 percent to achieve the projected BTU savings, a total capital investment of approximately $150 million would be required. The cumulative annual cost between 1977 and 1990 after tax credit would be $104 million.

Employment

TES is not expected to impact industry operations. However, development of a large-scale TES industry would result in new manufacturing, installation and service tasks. Data were not available for estimation.

H. INCREASED PRODUCTION OF NATURAL FERTILIZERS

1. Maximum Energy Savings

INTRODUCTION

Since natural gas is the basic raw material used in the production of fertilizer, this industry is fairly energy intensive. Therefore, the substitution of natural fertilizers, which are not energy intensive, is a possible source of significant energy savings.

There are several means of replacing manufactured fertilizers with natural fertilizers. Each means has its own set of potentials, complexities, and problems which require special analysis. The primary alternative sources of fertilizers are animal waste, sewage sludge, and crop rotation with legumes.

For purposes of this anaylsis, the use of animal waste was the alternative considered as a substitute for manufactured fertilizers. It has the advantage of being a good form of fertilizer, since it has the organic material, in particular nitrogen, necessary for good crop production. From a logistical standpoint, the use of animal waste is relatively convenient to the areas of usage and can be collected from a fairly small area. It does, however, have the drawback that the sodium in the animal waste tends to break down the soil if it is not washed away. This is a problem in irrigated areas where the sodium is likely to build up.

As in the case of other measures, the maximum potential energy savings were calculated by estimating the per unit energy savings in conjunction with the total number of units which could be produced. In the case of fertilizers, the total amount of animal waste from livestock and poultry feedlots was estimated first. The amounts of nitrogen, potassium and phosphates in that amount of animal waste were calculated based on current average mineral contents of livestock and poultry wastes.

These estimates were transformed into energy savings by assuming the nitrogen, potassium, and phosphates from the animal waste replaced manufactured fertilizers.[1] The amount of manufactured fertilizer thus replaced was multiplied by per unit energy requirements to arrive at total maximum potential energy savings.

RESULTS

Figure III-29 summarizes the estimation of the amount of energy required to produce nitrogen, phosphates, and potassium for fertilizers. (These figures do not include the energy required for transportation.)

In order to determine the relative importance of each fertilizer in assessing energy requirements, the energy consumed in 1971 to produce each mineral has been calculated, (Figure III-30). It is evident from this calculation that nitrogen, accounting for 87% of the total consumption, is by far the most important substance with respect to energy consumption.

The energy savings were calcualted by multiplying the amount of manufactured fertilizer which could be replaced by animal waste. The total waste from farm animals which is not now being used as fertilizer in 1973 was 207 million tons and the nitrogen, potassium and phosphates in that animal waste are shown in Figure III-31. By comparing these quantities to the total production of fertilizer in Figure III-30, it can be seen that the nitrogen, potassium, and phosphate content of the total animal fertilizer is a small fraction of the total fertilizer production, approximately 14% in the case of nitrogen.

The savings in energy resulting from the use of animal waste as fertilizer would be the amount of energy required to produce a comparable amount of nitrogen, potassium, and phosphates. The energy consumption rates for each component are shown in Figure III-30.

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[1] One unit of minerals from manufactured fertilizer was assumed to be equivalent to two units of minerals from animal waste because plants can use all of manufactured fertilizers immediately, whereas only a portion of the natural fertilizer could be used and not all in the first year.

[2] This estimate is based on a preliminary report by the Office of Solid Waste Management Programs. It represents the total annual waste from cattle, chickens, pigs and sheep in feedlots and confined. It was estimated in that report that 50% of the total (414 million tons) is already being marketed.

FIGURE III-29

ENERGY CONSUMED PER UNIT OF FERTILIZER PRODUCTION

	NATURAL GAS			FUEL OIL	ELECTRICITY	TOTAL[3]
	Feedstock (cu.ft/ton)	Energy (cu.ft/ton)	Total (cu.ft/ton)	(gal/ton)	(KWHr/ton)	(MMBTU/ton)
AMMONIA (centrifugal compressors)	22,219	15,908	38,127	9	54	41.1[4]
PHOSPHATES						
Sulfur Production	0	6,000	6,000	0	33	6.5
Total[1]		7 00	7,500	0	41	8.1
POTASSIUM	0	3,031	3,031	0	112	4.2

Source: Based on data from the Fertilizer Institute published in "Energy: The Name of the Game," by Bill White, Fertilizer Progress, Nov-Dec, 1973.

1. Energy consumed is assumed to be 80% of the total energy requirements for phosphate production (See The Task Force on Fertilizers, Dec., 1973, pg. 16)

2. Assumed to be the average of the energy required for

3. Conversion factors: 1032 BTU/cu.ft. of gas; .139 MMBTU/gal. of oil; 9,309 BTU/KWHr.

4. Since 82% of Ammonia is nitrogen, 49.9 MMBTU/ton is required to produce one ton of nitrogen.

FIGURE III-30

ENERGY CONSUMED BY THE FERTILIZER INDUSTRY IN 1971

	1971 PRODUCTION[1] (10^3 Tons)	ENERGY REQUIRED (MMBTU/TON)	ENERGY CONSUMED (10^{12} BTU)
NITROGEN	8,016	49.9	400
PHOSPHATES	4,803	8.1	39
POTASSIUM	4,400	4.2	18
TOTAL	17,219	33.1	457

[1] The U. S. Fertilizer Situation and Outlook, the Task Force on Fertilizers, Council for Agricultural Science and Technology, December, 1973.

FIGURE III-31

CALCULATION OF NITROGEN, POTASSIUM, AND PHOSPHATE CONTENT OF ANIMAL WASTE REMAINING AVAILABLE

(which is not now being marketed as natural fertilizer)

	1973	1977[4]	1980[4]	1985[4]	1990[4]
Animal Waste (10^6T)	207	224	237	261	289
Mineral Content					
Nitrogen[2] (10^3T)	1134	1227	1298	1430	1583
Potassium[2] (10^3T)	348	377	398	439	486
Phosphates[2] (10^3T)	844	913	966	1064	1178

ENERGY REQUIRED TO PRODUCE FERTILIZERS WITH EQUIVALENT MINERAL CONTENT

(10^{12} BTUs)

	1973	1977	1980	1985	1990
Nitrogen[3]	56.7	61.4	64.9	71.5	79.2
Potassium[3]	1.5	1.6	1.7	1.8	2.0
Phosphates[3]	6.9	7.5	7.9	8.7	9.7
Total	65.1	70.5	74.5	82.0	90.9

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[1] Based on a preliminary analysis by OSWMP. Derived from 1973 estimates of confined cattle, dairy cows, pigs, chickens, and sheep and average per animal generation of wet waste. Assumes 50% of the total generation is now being used for fertilizer.

[2] Assume .0055 metric tons of nitrogen per metric ton of animal waste, .0017 metric tons of phosphates, and .0041 metric tons of potassium . Derived from a preliminary report by OSWMP.

[3] Energy requirements for fertilizer production taken from Energy: The Name of the Game," by Bill White, Fertilizer Process, Nov., Dec., 1973. (For nitrogen 49.9 MMBTU/Ton; for phosphates, 8.1 MMBTU/ton; for potassium, 4.2 MMBTU/ton)

[4] Rates of increase equal to the high estimate given for food material in Resource Recovery and Source Reduction, Second Report to Congress, EPA, Table 5.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

The total amount of dry animal waste produced in confinement was estimated at 414 million tons in 1973.[1] Of this, approximately 50 percent or 207 million tons was marketed. Building on this assumption, approximately 50 percent of estimated future animal waste represents the supply potential for which maximum energy savings were calculated.

However, according to the U.S. Department of Agriculture,[2] for more than a year there has been little surplus natural fertilizer of that generally considered economically feasible for commercial use. This suggests that the future supply potential (50% of future animal waste) is not presently considered economically feasible for commercial use. Most commercially available natural fertilizer is currently being bought and used by farmers, due to major price increases in chemical fertilizer.

Given that the price of chemical fertilizer will probably not decrease, the economics of the free market suggest that the available marketable natural fertilizer will be used in the future as well. This assumption was supported by the spokesman from the U.S.D.A. Agricultural Research Service.

An additional feasibility factor mentioned by the Agricultural Research Service was that shipping of natural fertilizer had not turned out to be the difficulty that USDA had anticipated. Since farmers in the area of the feedlots, dairies, and poultry farms were buying the available supply, it was not necessary to add high processing and transportation costs to the price of natural fertilizer.

For purposes of this analysis, the 50% of supply presently consumed has been assumed to be the total amount readily marketable. However, if demand continues to increase, it is possible that a higher proportion of the total supply will be made available to the market (i.e. the less accessible and less economic supply). Since there is no data available to assess the above assumptions, it has been arbitrarily assumed that

65% of the estimated supply will reach the market. Using that assumption, 670 Trillion BTUs would be conserved between 1977 and 1990.

Estimates of nutrients in chemical fertilizer[1] indicate that natural fertilizers have approximately 2 percent the nutrient value of an equal weight of chemcial fertilizer. Therefore, a 50 to 1 ratio was assumed, with 50 tons of natural fertilizer roughly equal to one tone of chemical fertilizer.

The U.S. consumption of chemical fertilizer in 1973 was approximately 45,000,000 tons.[2] Using the estimated 65 percent available (or 134,000,000 tons) of the estimated available 207,000,000 tons of animal waste in 1973, the 50:1 ratio indicates that commercially available natural fertilizer can replace 2.7 million tons or 5 percent of the chemical fertilizer market. (The energy savings shown on the following figure include the natural fertilizer being used.)

IMPACTS

A summary of impacts is shown in Figure III-32.

Private Consumer

For the purpose of the analysis, it has been assumed that agriculture savings would be passed on to the consumer for a net decrease in food prices (or price increase avoidance) of $4.5 billion between 1977 and 1990.

Public Sector

Reduced natural gas and oil consumption could result in a cumulative reduction in imports of approximately $56 million between 1977 and 1990.

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[1] Natural fertilizer nutrient values--taken from MATHEMATICA table on this measure: one metric ton of natural fertilizer contains 3 kg. of nitrogen, 2 kg. of phosphates, and 3 kg. of potassium. EPA estimated nutrient values of one metric ton of chemical fertilizer as 20 percent (200 kg.) of nitrogen, 10 percent (100 kg.) phosphates, and 10 percent (100 kg.) potassium.

[2] The Fertilizer Institute spokesman.

FIGURE III-32

FERTILIZER IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	65.1	70.5	74.5	82.0	1,031
2. Estimated Feasible	42.3	45.8	48.4	53.3	670
B. Impacts (Millions of Dollars)					
1. Private Industry					
Chem. Fert. Industry	($484m)	($524m)	($554m)	($610m)	($7,700m)
Natural Fert. Indust.	$202m	$218m	$231m	$254m	$3,200m
2. Private Consumer					
Savings	$282m	$306m	$323m	$364m	$4,500m
3. Public Sector					
Government	NOT APPLICABLE				
Balance of Payments	$ 3.5m	$83.8m	$ 4.0m	$ 4.4m	$ 55.7m
4. Employment (Jobs)					
Chemical Fert. Industry	(9,195)	(9,725)	(10,716)	(11,879)	(11,879)
5. Environment (Percent Reduction)					
Particulate reduction	.10%	.10%	.10%	.10%	

Quality of Life

One of the most significant quality of life factors in promoting use of natural fertilizers lies in the discomfort caused by the odors.[1] There currently is limited use of natural fertilizers on farms near populas areas, due to the unpleasant odor it produces.

Scarce Materials or Resources

The major impact on scarce materials or resources increasing natural fertilizer use lies in the conservation of the diminishing natural gas supply, since natural gas is a prime ingredient in the manufacture of chemical fertilizers.

Environment

Fertilizer manufacturing is of three types: nitrogen, phosphate, and potash. In the nitrogen sector, air pollution is insignificant, since natural gas is the prime energy source. Significant water pollution, however, is entailed in fertilizer manufacturing, due primarily to ammonia compounds. Phosphate rock dust, air pollution, and fluoride water pollutants are important in the phosphate sector. In potash manufacture, dust emissions into the air are the main pollutants.

The substitution of natural fertilizer for manufactured fertilizer will serve to reduce the various pollution effects from fertilizer manufacturing. Unfortunately, insufficient data make it "very hard to correlate"[2] quantitatively energy reduction with pollution reduction in the fertilizer industry. As a very rough measure, however, pollutant reduction is proportionatal to energy reduction in the industrial sector. Hence, using total energy consumption projections[3] for the industrial sectors, about a 0.10% reduction in total particulate emissions could be anticipated due to this conservation measure. Particulate air pollutants are the priniciple pollutant in the industrial sector.

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[1] Private communication, U.S.D.A.

[2] Private communication, Environment Department, Fertilizer Institue, Washington, D.C., 1974.

[3] Energy through the year 2000, U.S. Department of Interior, 1972.

1977: .03%   1980: .04%   1985: .035%   1990: .035%

The overall pollutant reduction is very small, although the reduction in localized air and water pollution brought about through increased use of natural fertilizers may be much more significant.

One negative environmental impact of natural fertilizer use relates to its odor, which can cause discomfort near populated areas.

Private Industry

Use of natural fertilizer would directly displace chemical fertilizer sales. Recent price trends suggest that the maximum possible displacement will occur: 1 ton of chemical for each 50 tons of natural fertilizer used.[1] The world-wide trend toward fertilizer use has been increasing at a substantial rate. This demand is reflected by recent fertilizer export figures. In addition, private consumer home gardening and lawn care have continued to press the demand for fertilizer upward.

While quantitative estimates for private consumer demand and export demand have not been made, it is quite possible that fertilizer production would not decrease. Using this assumption, energy savings and cost impacts to the fertilizer industry can only be considered as avoidance impacts. It should also be noted that since this measure appears to be in effect already, the impacts are ongoing.

Estimated private industry impacts are principally in the fertilizer industry, both chemical and natural.

Between 1977 and 1990 an estimated 2.1 billion tons of natural fertilizer will be consumed. At an average price of \$1.50/ton, natural fertilizer suppliers would realize approximately \$3.6 billion in gross sales.[2] Assuming the 50 to 1 ratio, approximately 48 million tons of chemical fertilizer would be displaced.

Basing cost estimates on the current price of 20-10-10 fertilizer (\$180/ton)[3], an estimated \$7.7 billion dollars in chemical fertilizer sales would be lost between 1977 and 1990. The net industry impact would be a loss of \$4.5 billion in fertilizer sales.

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[1] Based on nutrient values of natural and chemical fertilizers.

[2] Fertilizer Institute.

[3] Local East Coast price quote to PMM & Co.

Agricultural industries (farmers) would realize a possible net savings for food production. The direct savings between 1977 and 1990 would be the $4.5 billion difference in cost between chemical fertilizers and the replacement of natural fertilizer. On a per unit basis, the cost savings would be:

Cost of chemical fertilizer per ton	$180
Cost of equivalent natural (50 tons)	$ 75
Net saving	$105

It is assumed that this saving would be passed along to the consumer and not retained by the agricultural industries.

The added labor and machinery associated with use of 50 tons natural in place of one ton of chemical would have to reduce the net savings. Data are not available to estimate the added labor/machine cost associated with natural fertilizer use within the framework of this analysis.

Employment

Based upon the reduced production of chemical fertilizer, approximately 11,900 jobs would not be created by 1990. 1970 industry total employment was approximately 31,000. This reduction in employment would be at least partially counterbalanced by the more labor intensive nature of natural fertilizer use. Data was not available to completely detail these job related effects.

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IV. ENERGY CONSERVATION IN THE COMMERCIAL SECTOR

A. INTRODUCTION

The Commercial Sector is very diverse and consists of a variety of buildings, such as office buildings, stores, schools, hospitals, etc. There exist no general studies of energy conservation which apply to all these types of buildings. Most of the recent studies have evaluated either specific (typical) buildings or have derived general energy-savings guidelines without significant quantitative analysis.

Thus for example, RAND[1,2] researchers have made detailed evaluation of typical commercial buildings in Los Angeles and have developed estimates of conservation potential based on the adoption of short term conservation measures in California. Similarly, studies at Oak Ridge[3] and HUD[4] have worked at specific energy system alternatives for buildings. On the other hand, GSA[5], NBS[6], and ASHRAE[7] have developed general guidelines and criteria for designing buildings. However, none of these efforts have resulted in estimates of national energy savings potential.

The accurate determination and representation of energy use in the commercial building sector poses a very difficult problem,

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[1] Salter and Morris, 1973

[2] Doctor, 1973

[3] Oak Ridge, 1974

[4] HUD has undertaken evaluations of Total Energy and Modular Integrated Utility Systems (MIUS) technologies to evaluate and demonstrate their potential for conservation

[5] GSA, 1974

[6] NBS, 1973

[7] ASHRAE, 1974

not the least of which is to define the commercial building sector itself. One major problem is whether multi-family apartment buildings are considered residential or commercial. Previous attempts, such as the SRI Study,[1] have relegated what energy is left over to the commercial sector, after accounting for other sectors and then attempted to construct whatever component of that sector was of interest.

In this effort, multi-family buildings are considered residential and the commercial sector is defined to include only offices, stores, hospitals, schools, religious buildings. An attempt has been made to construct the energy use in commercial buildings "from the ground up" so as to enable the application of various energy conservation measures in order to estimate the overall impact of these in the 1975-1990 time frame.

The six energy conservation measures evaluated in this study are listed in Figure IV-1.

It is reemphasized that the evaluations presented in the following pages are based upon the major assumption that each measure is independent and would be implemented to the exclusion of each other measure. Hence, neither energy savings nor associated impacts are necessarily additive.

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[1] SRI, 1972.

FIGURE IV-1

ENERGY CONSERVATION MEASURES IN THE COMMERCIAL SECTOR

Serial No.	Conservation Measure	Implementation Strategy
C-1	Reduction in ventilation air flow standards	Modification of local building code regulations
C-2	Reduction in air flow within buildings	Modification of local building code regulations, design and operation of systems
C-3	Adjustments in temperature control	Promote voluntary adjustments by season, day of week, and time through public appeal and education
C-4	Increased use of task lighting	Modification of local building codes, regulations, uses
C-5	Use of Total Energy Systems	Tax credits for use of such systems
C-6	Use of Solar Energy/Heat Pumps	Tax credits for use of such systems

B. GENERAL APPROACH AND SUMMARY OF ENERGY SAVINGS

Since the quantity and type of energy used in commercial buildings varies considerably with the class of building, and to some degree with the size of building, an attempt was made to disaggregate the Commercial Sector into the following categories:[1]

1. Stores and Offices
2. Religious
3. Educational
4. Hospital and Institutional
5. Public Buildings (including military)
6. Miscellaneous and other

In order to further estimate the type of energy use for each class, it was necessary to develop the total size of each segment of the sector. An estimate of the square footage of each class of building was obtained by analyzing data from the Statistical Abstract of the United States. The estimated square feet of commercial buildings by type are shown in Figure IV-2 . For each type of building, estimates of electrical and fossil fuel energy consumption per square foot were made and based on these, the total electric and fossil energy consumption was calculated (see Figure IV-2).

The calculated value of total commercial energy is lower than estimates made by SRI[2]. The comparison of the calculated value with published figures from the Bureau of Mines[3] and the MATHEMATICA Energy Data Base[4] can only be made after aggregating the residential and commercial sectors, and indicates an "other and unaccounted for" category of approximately 10%. Since the published figures for

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[1] Based on data from F. W. Dodge reported in Commerce, 1973 and Statistical Abstract of the U. S.

[2] SRI, 1972

[3] Bureau of Mines, Mineral Industry Surveys for various fuels

[4] See Appendix A

FIGURE IV-2

COMMERCIAL ENERGY CONSUMPTION - 1970

CLASS	DESCRIPTION	Sq. Ft.[1] (MILLIONS)	ELECTRICITY		FOSSIL FUEL	
			KWH/SQ.FT.[2]	Billion KWH	Thousand BTU/Sq. Ft.[2]	TRILLION BTUs
1	RETAIL & OFFICE	7,590	20	150	150	1,138
2	RELIGIOUS	1,800	8	14	100	180
3	EDUCATIONAL	5,040	10	50	150	756
4	HOSPITALS	1,500	30	45	250	375
5	PUBLIC BUILDINGS	1,580	10	16	150	237
6	SOCIAL & OTHERS	4,100	15	62	150	615
TOTAL		21,610	-	337	-	3,301
EQUIVALENT TOTAL SOURCE ENERGY (trillions of BTU's)				3530×10^{12} BTU[3]$_t$		3,301

1. Estimated from data in U. S. Dept. of Commerce, Construction Reviews and Statistical Abstract of the U.S.

2. Based on Spielvogel, L. Commercial Energy Conservation, Report Submitted to MATHEMATICA, Inc., August, 1974.

3. Electricity converted at 3412 BTU/KWH x 3.07

commercial energy consumption are not available, it is not possible to determine how accurate the calculated values are. However, discussions with architects-engineers familiar with the commercial sector indicate that these are "reasonable".

In order to estimate the overall potential impact of each of the energy conservation measures on the entire commercial sector, estimates were made of the energy savings by energy type in each class of commercial building. This was done by computing an energy savings factor separately for electric and fossil fuel energy that would reflect the consumption with implementation of the measure compared to no implementation.

The step-by-step approach is summarized below:

1. For each building type the percent of energy which would be affected by the particular conservation measure was estimated for electric and fossil fuel energy.
2. The percent saving due to the adoption of the measure was estimated for electric and fossil energy.
3. The percent saving was applied to the portion of the energy estimated in Step 1 to determine the total conservation impact.

One of the major problems with most energy conservation measures in commercial buildings is the shift of energy use. This shift can occur from summer to winter, from day to night, from lighting to space heating energy, etc. What may be very efficient in winter can be inefficient in summer, and vice versa.

A good example of this is in the air conditioning of computer rooms. Most computer rooms use mechanical cooling 365 days per year with minimum ventilation air. When the outdoor temperature is below 55°F, outdoor air could be used to provide 100% of the cooling; thereby enabling shutoff of the mechanical cooling system. However, when this is done, it is necessary to humidify the outdoor air, thereby using as much or more energy, although of a different type, not to mention the filtration and odor control problems.

The percentage reduction in energy use or saturation of any one measure is very much a function of economics, practicability, local building codes and practices, fuel and energy cost and availability, and in the case of existing buildings, the need to renovate or repair. Other factors include performance requirements and reliability.

Decisions such as these are made on each individual building, and it is extremely difficult to generalize them. The estimates given in the subsequent discussion are, to a large extent, based on engineering judgment and empirical evidence.[1]

A summary of the estimated maximum technologically feasible savings and the achievable savings is given in Figure IV-3.

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[1] As described in Spielvogel, 1974.

FIGURE IV-3

SUMMARY OF ENERGY SAVINGS

(Trillions of BTUs)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Ventilation	1153	1313	1617	1921	0	661	1434	1647
Air Flow	124	141	174	206	0	66	164	191
Temperature Control	1000	1139	1403	1667	586	703	770	885
Task Lighting	193	219	270	321	0	133	159	192
Total Energy Systems	7.5	17.2	35.9	54.5	.08	1.5	6.2	12.7
Solar Energy/Heat Pumps	105	288	717	1094	0	17	43	109

C. BASELINE PROJECTIONS USED IN CALCULATIONS

The energy savings resulting from the implementation of the various energy conservation measures were calculated as the product of the percentage energy savings (as derived in Sections D through H) and the total commercial energy demands.

The energy demand projections by the entire commercial sector were based on the residential/commercial energy projections made in the Total Energy Resource Analysis Model as submitted to FEA by the American Gas Association. These projections are based on the industrial relationship between residential/commercial energy demand and personal income. Projections of personal income were those made by the Department of Commerce.[1] The projections are shown in Figure IV-4.

For the ventilation, task lighting, temperature control, and air flow measures, it was assumed that the projected maximum saturations are realizable by 1977. This is due to the fact that the capital requirements to implement these measures are not great.

In the case of the total energy systems and the solar/heat pump measures, the capital requirements are significant. Therefore, it was assumed that the maximum saturation will be reached gradually until 1990. The resultant percentage savings for each measure are shown in Figure IV-5.

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[1] Dept. of Commerce, 1971.

FIGURE IV-4

BASELINE PROJECTIONS OF COMMERCIAL ENERGY DEMAND

(10^{12} BTU)

YEAR	RESIDENTIAL/ COMMERCIAL[1]	COMMERCIAL		
		ELECTRIC	FOSSIL FUEL	TOTAL
1970	14,886	3,162[2]	3,301[2]	6,463
1977	22,046	4,683[3]	4,889[3]	9,572[1]
1980	25,114	5,335[3]	5,569[3]	10,904[3]
1985	30,931	6,570[3]	6,859[3]	13,429[3]
1990	36,752	7,807[3]	8,150[3]	15,957[3]

1. Total Energy Resource Analysis Model as submitted to the FEA by the American Gas Association.

2. See Figure IV-1.

3. Projected in proportion to total residential/commercial projections. (See Appendix A)

FIGURE IV-5

PERCENTAGE ENERGY SAVINGS RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATION MEASURES IN THE COMMERCIAL SECTOR

MEASURE	ENERGY	1977	1980	1985	1990
VENTILATION	Electric	7.7	7.7	7.7	7.7
	Fossil Fuel	16.2	16.2	16.2	16.2
TASK LIGHTING	Electric	15.7	15.7	15.7	15.7
	Fossil Fuel	-11.1	-11.1	-11.1	-11.1
CONTROL	Electric	8.1	8.1	8.1	8.1
	Fossil Fuel	12.7	12.7	12.7	12.7
AIR FLOW	Electric	3.9	3.9	3.9	3.9
	Fossil Fuel	-1.2	-1.2	-1.2	-1.2
SOLAR/HEAT PUMPS	Electric	.8	2.0	4.1	6.1
	Fossil Fuel	2.9	7.1	14.3	21.4
TOTAL ENERGY	Electric*	0.	.03	.09	.16
	Fossil Fuel	--	--	--	--

Source: See sections C through H.

*Fossil fuel saving as a fraction of electric power demand.

D. REDUCTION IN VENTILATION AND AIR FLOW STANDARDS

1. Maximum Energy Savings

VENTILATION

Current practice in the design and operation of heating and air conditioning in commercial buildings provides substantial proportions and quantities of ventilation air for the occupants of buildings. These requirements are usually dictated by building codes or by "good practice". Research into the background of most of these codes has shown that, for the most part, they are quite arbitrary in their requirements for ventilation air. Many buildings have been built without any ventilation air, and in many of these cases, the difference is not discernible.

When energy was inexpensive and readily available, little concern was expressed about ventilation air. Now it is felt that these ventilation requirements can be considerably reduced with little or no impact on the occupants.

It is believed that current ventilation standards (measured in number of cubic feet of fresh air per minute per person) can be reduced in many situations without compromising comfort[1,2].

Ventilation air influences both fossil and electric energy, principally for heating, humidifying, cooling and dehumidifying outside air. Buildings such as in Classes 3 and 4 have high ventilation requirements usually mandated by codes or Government requirements.

Systems exist for transferring energy from the exhaust air to the incoming fresh air which will preheat the input air in the

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[1] Spielvogel, 1974.

[2] Large, 1973.

winter and precool it in the summer.[1] Also, exhausted air from buildings can be used in the winter for snow melting on sidewalks, driveways and ramps by discharging the warm air through tiles under the outdoor surface.[2,3]

The calculation of percentage energy savings from the adoption of this measure is shown in Figure IV-6. The maximum technologically feasible savings are shown in Figure IV-3.

REDUCTION IN AIR FLOW WITHIN BUILDINGS

The quantity of air supplied for heating and air conditioning is usually determined by the peak expected cooling loads. In most buildings, the actually experienced cooling loads are lower than those anticipated in the design, and they change frequently due to changes in function and layout of the spaces being served. Air flow quantities are rarely reduced to match the loads that exist.

In existing buildings, when lighting and other cooling loads are reduced, the air flow can be reduced correspondingly.

Since, in a given system, fan energy varies as the cube of the air flow, these reductions in air flow can significantly reduce energy consumption, both for the fan itself as well as heating and cooling. Further, in most buildings the fans run at full load during all operating hours, whereas heating and cooling equipment is modulated in capacity to meet the actual loads that are occuring at the time.

Airflow reductions can easily be achieved in existing buildings and this measure, therefore, offers the advantages of low first cost and minimum inconvenience. The calculation of percentage energy savings from this measure are shown in Figure IV-7. The maximum technolgically feasible savings are shown in Figure IV-3.

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[1] Progressive Architecture, 1971

[2] Large, 1974

[3] Dubin, 1974

FIGURE IV-6

CALCULATION OF THE PERCENTAGE SAVINGS IN THE COMMERCIAL SECTOR RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATION MEASURES

MEASURE: DECREASED VENTILATION

ELECTRICITY

CLASS	1970 CONSUMPTION[1] (Billion KWH)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Billion KWH)	%[3]	AMOUNT (Billion KWH)	
1. Stores & Offices	150	15	22.5	50	11.3	7.5
2. Religious	14	10	1.4	30	.4	3.0
3. Educational	50	10	5.0	50	2.5	5.0
4. Hospital and Institutional	45	35	15.7	40	6.3	14.0
5. Military	16	10	1.6	50	.8	5.0
6. Miscellaneous	62	15	9.3	50	4.6	7.5
TOTAL	337	16.5	55.6	46.7	26.0	7.7

FOSSIL FUEL HEAT

CLASS	1970 CONSUMPTION[1] (Trillion BTU)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Trillion BTU)	%[3]	AMOUNT (Trillion BTU)	
1. Stores & Offices	1138	30	341.4	50	170.7	15.0
2. Religious	180	10	18.0	30	5.4	3.0
3. Educational	756	40	302.4	50	151.2	20.0
4. Hospital and Institutional	375	60	225.0	40	90.0	24.0
5. Military	237	20	47.4	50	23.7	10.0
6. Miscellaneous	615	30	184.5	50	92.3	15.0
TOTAL	3301	33.9	1118.7	47.7	533.3	16.2

1. Source: See Figure IV-1.
2. Applied only to that portion of the energy consumption affected by the conservation measure.
3. Based on Spielvogel, L., Commercial Energy Conservation, report submitted to MATHEMATICA, Inc., 1974.

FIGURE IV-7

CALCULATION OF THE PERCENTAGE ENERGY SAVINGS IN THE COMMERCIAL SECTOR RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATION MEASURES

ELECTRICITY

MEASURE: REDUCED AIR FLOW

CLASS	1970 CONSUMPTION[1] (Billion KWH)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Billion KWH)	%[3]	AMOUNT (Billion KWH)	
1. Stores & Offices	150	10	15.0	50	7.5	5.0
2. Religious	14	0	0	–	–	–
3. Educational	50	10	5.0	30	1.5	3.0
4. Hospital and Institutional	45	10	4.5	40	1.8	4.0
5. Military	16	0	0	–	–	–
6. Miscellaneous	62	10	6.2	40	2.4	4.0
TOTAL	337	9.1	30.7	43.3	13.3	3.9

FOSSIL FUEL HEAT

CLASS	1970 CONSUMPTION[1] (Trillion BTU)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Trillion BTU)	%[3]	AMOUNT (Trillion BTU)	
1. Stores & Offices	1138	10	113.8	-20	-22.8	-2.0
2. Religious	180	0	0	–	–	–
3. Educational	756	10	75.6	-10	-7.56	-1.00
4. Hospital and Institutional	375	10	37.5	-10	-3.75	-1.00
5. Military	237	0	0	–	–	–
6. Miscellaneous	615	10	61.5	-10	-6.15	-1.00
TOTAL	3301	8.7	288.4	-14.0	-40.3	-1.2

1.Source: See Figure IV-1.

2.Applied only to that portion of the energy consumption affected by the conservation measure.

3.Based on Spielvogel, L., Commercial Energy Conservation, report submitted to MATHEMATICA, Inc.,1974.

2. Achievable Energy Savings and Impacts

IMPLEMENTATION STRATEGY

The discussions of implementation feasibility of ventilation and air flow measures were combined because the two measures were treated as variations of the same thing by experts in the field. (The energy savings and cost impacts were treated separately, however.) Ventilation deals with the flow of air from the outside to the inside of a building and vice versa; air flow refers to the circulation of air within a building. Air flow and ventilation levels are set and approved when buildings are originally constructed. Reduction in ventilation and air flow levels of commercial buildings requires only an adjustment of existing equipment which a building engineer can do easily.[1] The separate energy savings and associated impacts for the two measures are summarized in Figures IV-8 and IV-9.

ENERGY SAVINGS REALIZATIONS

The estimates of maximum energy savings from reduced ventilation and air flow standards in both new and existing buildings between 1977 and 1990 cannot be fully achieved because of two major factors: time required to change the building codes and time for buildings to adopt the new standards.

Implementation time is estimated at two and a half years (1976-1979), based upon information provided by a staff member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and the D.C. building code board research department. Most states follow the ventilation and air flow standards set by ASHRAE and would not be included to change the code standards unless ASHRAE provided research indicating that lower minimum standards would still be adequate for health.[2]

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[1] National Environmental Systems Contractors Association (NESCA) spokesman.

[2] Research department spokesman, D.C. Bureau of Buildings, Housing and Zoning.

Again, a staff member at ASHRAE estimates that it would take approximately one year for any research on its part to be completed, 6-8 months for dissemination of the results and one year before local building codes put the new standards into effect. Therefore, from 1977 to 1979, the energy savings from reduction in outside air flow would be zero.

If the new code standards went into effect in 1979, it is assumed that approximately 50 percent of commercial buildings would be in compliance by 1980 (includes both new construction and existing buildings). This estimate is based upon the fact that (a) new commercial construction would not be able to incorporate the modifications until 1980 and (b) compliance of existing buildings is implicitly voluntary, since inspection of older buildings for ventilation and air flow levels is generally on a "complaint" basis only.

There probably would never be 100 percent compliance on the part of the managers of existing buildings to the new standards since compliance is implicitly voluntary; however, there were no data on which to base a reduction in savings through 1990. Therefore, 100 percent compliance was assumed for both measures from 1985 on. As shown in Figures IV-8 and 9, approximately 72 percent of the cumulative maximum potential energy savings for ventilation, (15,819 Trillion BTUs) and 73 percent of the cumulative maximum potential savings for air flow (1,700 Trillion BTUs) would be realized.

Other nonquantitative factors important in the implementation of these measures include the necessity for action or incentive by EPA (e.g., a grant) to encourage ASHRAE to carry out the initial research on standards reduction and a program to upgrade building inspector air flow measurement knowledge.

One spokesman for the National Environmental Systems Contractor Association (NESCA) cited an industry survey that indicates many municipal ventilation and air flow inspectors lacked the knowledge to measure different air flow levels within a building. An education program would have to be undertaken to train these inspectors in the modified standards and how to verify compliance.

IMPACTS

Private Consumer

Consumers would not benefit directly from reduced ventilation and air flow standards in the commercial sector. Indirect benefits such as lower retail prices and delayed price increases could result from shopping center and other retail center reduced operating costs; however, such consumer savings were not estimated.

Public Sector

Reduced oil imports associated with power generation would result from decreased level of commercial energy consumption for both ventilation and air flow conservation measures. As shown in Figures IV-8 and 9, an approximate $1.3 billion and $0.14 billion in direct import costs would be avoided by 1990.

In addition to import impact, it is probable that the federal government will incur some direct program costs such as those for research grants and educational programs, if the two measures were to be implemented.

Scarce Materials/Resources

There are no anticipated scarce materials and/or resources problems associated with either of these measures.

Quality of Life

Comfort is the major quality of life parameter affected by reducing ventilation and air flow standards. While almost no data exist to quantify comfort as a function of ventilation and air flow, an important concern was raised by a spokesman for ASH (Action on Smoking and Health), an organization dedicated to protection the rights and health of non-smokers. He stated that such measures could have a "very, very adverse effect on the already dangerous carbon monoxide levels." ASH, in fact, is encouraging the Department of Labor to set minimum carbon monoxide (CO) standards for offices and factories. The ASH spokesman noted that most current ventilation and air flow levels are substandard in terms of preventing CO accumulation in commercial buildings. In addition to CO buildup, it is also anticipated that added humidity accumulation will add to levels of discomfort (although to an unknown level).

FIGURE IV-8

VENTILATION IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	1,153	1,313	1,617	1,921	21,405
2. Estimated Feasible	0	657	1,617	1,921	15,819
B. Impacts (Millions of Dollars)					
1. Private Industry		Insufficient Data			
Commercial Building Owners/Operating (Savings)	0	$2,872m	$7,067m	$8,396m	$69,139m
Capital Costs		Not Estimated			
2. Private Consumer		Not Estimated			
3. Public Sector					
Government		Insufficient Data			
Balance of Payments	0	$ 55m	$ 136m	$ 161m	$ 1,329m
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	0	1.3%	2.4%	1.8%	

FIGURE IV-9
AIR FLOW IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	124	141	174	206	2,299
2. Estimated Feasible	0	71	174	206	1,700
B. Impacts (Millions of Dollars)					
1. Private Industry		Insufficient Data			
Commercial Building					
Owner/Operator Savings	0	$ 310m	$ 759m	$ 899m	$ 7,418m
Capital Costs		Not Estimated			
2. Private Consumer		Not Estimated			
3. Public Sector					
Government			Insufficient Data		
Balance of Payments		$ 6m	$ 15m	$ 17m	$ 143m
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	0	.14%	.26%	.19%	

While there are little quantitative data available for evaluation of the quality of life impacts from air flow and ventilation reduction, it is assumed that perceived comfort levels will be negatively affected.

Environment

Because of the proportion of relatively clean burning natural gas used in heating and cooling of commercial structures, the air pollution reduction effects of these measures are limited relative to total SO_2 produced by all energy sources.[1] As shown in Figures IV-8 and IV-9, 1.8 and 0.19 percent reductions of total sulfur dioxide would result by 1990 for the ventilation and air flow measures respectively. A majority of the SO_2 emissions will be due to decreased use of fossil fuels for electric power generation.

In absolute terms, ventilation reduction will result in avoidance of 216.5×10^6 lbs. while air flow reductions would result in avoidance of approximately 25.1×10^6 lbs.

Private Industry

While no data was developed to indicate the nature and magnitude of impacts on industry, it appears that neither measure, reduced ventilation or air flow, is likely to have a significant effect in terms of capital expenditures. As shown in Figures IV-8 and IV-9, building owners and operators would realize significant savings in energy cost for both the reduced ventilation and reduced air flow measures.

Employment

It is possible that additional jobs for building inspectors would be created. However, there is no basis for estimating the number of jobs that would be created.

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[1] It is likely that the natural gas saved would be used to substitute for other fuels in the commercial and other sectors. However, the environmental effects of such substitution were not evaluated by PMM Co.

E. ADJUSTMENT IN TEMPERATURE CONTROL

1. Maximum Energy Savings

Commercial buildings often have sophisticated temperature control systems operated in an unsophisticated manner. The obvious result of this situation is the wasting of energy. Improved management of temperature control in buildings could, in many cases, save between 10% and 15% of total building energy.

Much energy is wasted controlling temperatures of unoccupied buildings. This energy could be conserved by reducing or shutting off the systems when the building is not occupied. It is important to match system operating hours closely with occupancy hours. Although there is a tradeoff, with additional energy required to regain control of the occupied environment, in most cases, there is a net gain in energy conserved.

Control of heating and air conditioning systems can have a substantial effect on energy required for heating, humidifying, cooling and dehumidifying. The major potentials for energy conservation lie in reduced operating hours and in more optimum control of systems. Optimum control primarily deals with the manner in which heating and cooling media are operated to achieve individual room control in commercial buildings. The use of individual room control in central heating and cooling systems generally requires the mixing of some hot and some cold air or water to achieve control.

The calculation of percentage energy savings is shown in Figure IV-10. Maximum savings are shown in Figure IV-3.

2. Achievable Energy Savings and Impacts

IMPLEMENTATION STRATEGY AND ACHIEVABLE SAVINGS

As in the residential sector measure on thermostat control, this measure would be implemented voluntarily through public appeal and education programs. Maximum savings estimates were reduced based on the continuous National Survey data

FIGURE IV-10

CALCULATION OF THE PERCENTAGE ENERGY SAVINGS IN THE COMMERCIAL SECTOR RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATION MEASURES

MEASURE: ADJUSTED TEMPERATURE CONTROL

ELECTRICITY

CLASS	1970 CONSUMPTION[1] (Billion KWH)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Billion KWH)	%[3]	AMOUNT (Billion KWH)	
1. Stores & Offices	150	20	30.0	50	15.0	10.0
2. Religious	14	10	1.4	30	.42	3.0
3. Educational	50	10	5.0	40	2.0	4.0
4. Hospital and Institutional	45	20	9.0	50	4.5	10.0
5. Military	16	10	1.6	30	.48	3.0
6. Miscellaneous	62	20	12.4	40	4.96	8.0
TOTAL	337	17.6	59.4	46.1	27.4	8.1

FOSSIL FUEL HEAT

CLASS	1970 CONSUMPTION[1] (Trillion BTU)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Trillion BTU)	%[3]	AMOUNT (Trillion BTU)	
1. Stores & Offices	1138	25	284.5	50	142.3	12.5
2. Religious	180	20	36.0	30	10.8	6.0
3. Educational	756	30	226.8	50	113.4	15.0
4. Hospital and Institutional	375	40	150.0	40	60.0	16.0
5. Military	237	30	71.1	20	14.2	6.0
6. Miscellaneous	615	25	153.8	50	76.9	12.5
TOTAL	3301	27.9	922.2	45.3	417.6	12.7

1. Source: See Figure IV-1.
2. Applied only to that portion of the energy consumption affected by the conservation measure.
3. Based on Spielvogel, L., Commercial Energy Conservation, report submitted to MATHEMATICA, Inc., 1974.

which indicated that approximately 60 percent of the people turned down their thermostats during the fuel crisis.[1]

If 60 percent of people in residences adjusted their thermostats as a result of the national appeal, at least that percentage of commercial building owners and managers should comply. The profit motive present in the commercial sector would be an added incentive to adjust thermostats to save fuel and electricity bills.

The drawbacks to the feasibility of this measure's complete implementation include:

- the difficulty in maintaining voluntary compliance over many years through public appeal and education alone (no enforcement mechanism); and
- the administrative structure necessary to carry on such a national program.

The cumulative energy savings that could be achieved by this measure are estimated at 10,489 Trillion BTUs by 1990 (see Figure IV-11).

Private Consumer Cost/Savings

Reduced commercial use of energy as a result of thermostat controls would have little direct impact on consumers. Such savings have not been estimated.

Public Sector Cost/Savings

The government impact of implementing thermostat controls in the commercial sector would be the cost of an information dissemination and public appeal program. FEA estimates it is encountering direct expenses of $100,000 per year to promote the lowering of thermostats in the residential sector.[2] Cost for the commercial sector would probably be similar, or $1.4 million by 1990. Balance of payments would be improved as a result of reduced fuel imports. This total would be approximately $3.4 billion by 1990.

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[1] Continuous National Survey, Energy Related Data, National Opinion Research Center, February 1974.

[2] Estimate from FEA Office of Energy Conservation, Public Information Office.

Materials/Resources

There are no anticipated materials/resources problems associated with this measure.

Quality of Life

Comfort is the most important parameter in this measure. For a quantitative disucssion of comfort in relation to temperature control, the reader is referred to the thermostat measure in the residential sector discussion. As was shown there, minimal comfort disruption would result from energy reduction through temperature control.

Environment

As shown in Figure IV-11, there is only limited overall percent reduction in total sulfur dioxide emissions. A more significant effect of more than 6 percent SO_2 reduction would be realized in terms of local pollutants from commercial energy sources.

Private Industry Cost/Savings

The primary impact of thermostat controls would be reduced power and fuel costs to commercial enterprises. Based upon previously quoted energy prices, total cumulative savings in this sector would be approximately $50 billion by 1990.

Employment

No significant employment impacts were identified for this conservation measure.

FIGURE IV-11

THERMOSTAT SETTING IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	1,000	1,139	1,403	1,667	18,752
2. Estimated Feasible	600	683	841	1,000	11,143
B. Impacts (Millions of Dollars)					
1. Private Industry Commercial Building Owners/Operators	$ 2,884m	$ 3,283m	$ 4,042m	$ 4,807m	$ 53,562m
2. Private Consumer		Not Estimated			
3. Public Sector					
Government	($0.1m)	($0.1m)	($0.1m)	($0.1m)	($.14m)
Balance of Payments	$ 62m	$ 71m	$ 87m	$ 104m	$ 1,159m
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	.15%	.17%	.16%	.17%	

F. INCREASED USE OF TASK LIGHTING

1. Maximum Energy Savings

Current practice in the design of lighting systems for commercial buildings provides nearly uniform lighting levels throughout occupied spaces. Lighting that provides such illumination for only the tasks to be performed, where they are performed, can substantially reduce electric consumption. This, in turn, reduces the requirements for air conditioning. On the other hand, reducing the lighting energy will have a negative impact on heating energy.

Light-intensity standards (which are incorporated into many building codes, and used by Boards of Education, industries and commercial developers) recommended by the Illuminating Engineering Society have more than tripled in the last fifteen years, and may now be set at levels which have neither physiological nor psychological bases.[1] The current design philosophy developed by the lighting industry to maintain a uniformly high level throughout an area rather than to direct the most light to the work area results in energy consumption for lighting which could be reduced by 50%.

A significant saving of the energy consumed by projected construction can be a realistic objective for new buildings, and a reduction in light usage is also realizable in existing buildings. The calculation of the percentage energy savings is shown in Figure IV-12. The maximum energy savings are shown in Figure IV-3.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

Many of the factors just discussed for the ventilation and air flow measures would also apply to the task lighting measure. The implementation strategy calls for changes in local building code lighting regulations.

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[1] Stein, 1971.

FIGURE IV-12

CALCULATION OF THE PERCENTAGE ENERGY SAVINGS IN THE COMMERCIAL SECTOR RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATIONS MEASURES

MEASURE: INCREASED TASK LIGHTING

ELECTRICITY

CLASS	1970 CONSUMPTION[1] (Billion KWH)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Billion KWH)	%[3]	AMOUNT (Billion KWH)	
1. Stores & Offices	150	60	90.0	30	27.0	18.0
2. Religious	14	–	–	–	–	–
3. Educational	50	75	37.5	20	7.5	15.0
4. Hospital and Institutional	45	30	13.5	25	3.4	7.5
5. Military	16	60	9.6	40	3.8	24.0
6. Miscellaneous	62	60	37.2	30	11.2	18.0
TOTAL	337	55.7	187.8	28.2	52.9	15.7

FOSSIL FUEL HEAT

CLASS	1970 CONSUMPTION[1] (Trillion BTU)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Trillion BTU)	%[3]	AMOUNT (Trillion BTU)	
1. Stores & Offices	1138	50	569.0	-40	-227.6	-20.0
2. Religious	180	–	–	–	–	–
3. Educational	756	60	453.6	-20	- 90.7	-12.0
4. Hospital and Institutional	375	20	75.0	-10	- 7.5	- 2.0
5. Military	237	30	71.1	-15	- 10.7	- 4.5
6. Miscellaneous	615	25	153.8	-20	- 30.8	- 5.0
TOTAL	3301	40	1322.5	27.8	367.3	-11.1

1. Source: See Figure IV-1.
2. Applied only to that portion of the energy consumption affected by the conservation.
3. Based on Spielvogel, L., Commercial Energy Conservation, report submitted to MATHEMATICA, Inc., 1974.

Most designers follow the general guidelines of the Illuminating Engineering Society (IES) in setting illumination levels, and these guidelines have for many years suggested that lighting be appropriate to and focused on the task. According to an IES spokesman, however, the overriding factor for most builders is cost, with the initial cost of task lighting being higher than uniform illumination at the level required for brightly lit tasks. Therefore, strong implementation of the measure would require incorporation of IES standards into mandatory building codes.

A few states have already incorporated IES standards into school building specifications and some local areas have written the standards into building codes.[1] However, the majority of building codes merely reference to the IES guidelines as recommendations.

The maximum energy savings were reduced by one major factor: since most builders follow IES recommendations and the majority of building codes reference IES standards, it would be necessary to have IES guidelines state task lighting recommendations more specifically. Revision of these guidelines is an ongoing process; however, it would probably take some time for the IES to research and release definitive standards. Then, according to the implementation strategy, these new guidelines would have to be adopted into local building codes--on the average, a one-year or more approval process.

As a result there would be zero savings from implementation until 1980 (see Figure IV-11). From 1980 on, full saving realization was assumed because there were no quantifiable data on which to base actual energy savings that could be achieved. Cumulative energy savings realized are estimated at 89 percent relative to potential energy savings between 1977 and 1990.

---

[1] Dugas, et al, 1974

FIGURE IV-11

TASK LIGHTING IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	193	219	270	321	2,343
2. Estimated Feasible	0	133	159	192	1,978
B. Impacts (Millions of Dollars)					
1. Private Industry					
Commercial building owners/ operators savings	0	$779m	$932m	$1,125m	$10,371m
commercial building owners/ capital cost		Insufficient Data			
2. Private Consumer		Not Estimated			
3. Public Sector					
Government		Insufficient Data			
Balance of Payments	0	42.7 m	50.9 m.	61.2 m.	634.2 m.
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	0	.028%	.028%	.029%	

The other important factors in implementation of this measure include the difficulty of enforcing task lighting, especially in existing buildings. While reduction in current illumination levels is fairly simple (a general electrician can do it)[1], there is currently no existing mechanism to see that this reduction is enforced. In addition to having building codes mandate lower illumination levels and task lighting (presently, the majority of them recommend), it would be necessary to develop an inspection system to regulate the standards. Such a system would have large manpower requirements.[2]

In the area of attitudinal factors, the IES spokesman mentioned that desk lamps, which are basic to the commercial task lighting concept, are disliked by many office workers. Building managers are also adverse to any form of task lighting which limits their ability to interchange office spaces easily for different types of activities and tenants.

Private Consumer

There probably would be no discernable cost impact on private consumers.

Public Sector

Because the implementation strategy for tasks lighting calls for local building codes, the measure will result in some cost to local government encountered in the administration of the new building code lighting regulations. (Since there are currently few such enforced regulations in the United States, no cost data are available.)

Import costs could be reduced by approximately $249 million between 1977 and 1990.

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[1] Illuminating Engineering Society spokesman.

[2] Dugas et al, 1974.

[3] Interior, 1972. Calculations from Dupree and West reveal that well over 90% of U.S. electricity in 1971 was produced from domestic sources of energy.

Materials/Resources

There are no anticipated materials/resources problems associated with this measure.

Quality of Life

A recent study[1] has indicated that a significant 50% reduction of lighting levels would be acceptable for working areas, and would not impair comfort. Furthermore, it is apparent that a reduction of non-working lighting levels will result in no decrease in work efficiency or comfort.

It is also important to note that a uniformly lit room does not provide the optimum visibility for office and work tasks. Hence, comfort can actually be increased through task lighting, while energy consumption is decreased.

Environment

The task lighting measure directly affects electricial power generation pollutants. Therefore, particulate and SO_2 emissions from coal, in particular, can be reduced through measure implementation, although not to a large extent.

As shown in Figure IV-11, the measure would result in an annual SO_2 reduction of about 0.3% of total sulfur dioxide emissions.

---

[1] Energy Conservation Study, EPA/OPE.

[2] National Coal Association.

Private Industry Cost/Savings

The reduced energy consumption as a result of task lighting would lend to cumulative saving to building owners and operators of $17.4 billion by 1990.

The retrofitting of existing commercial structures for task lighting may result in some costs to owners of commercial buildings, but no data are available on thes costs because uniform task lighting standards have not been adopted nationwide. In addition, data collection is complicated by the fact that costs will vary with the dozens of different building configurations in the commercial sector, e.g., high-rise, low-rise, church, school, shopping center, military base.

Since desk lamps are a component of task lighting, there would be some stimulation of lighting fixture companies' production of desk lamps as well as specialized overhead lighting fixtures. It was not possible to quantify the extent of this impact, nor the impact of the fluorescent and other light manufacturers affected by change in demand patterns (e.g. overhead versus desk tubes).

There will be an overall impact to the commercial sector in terms of cost of task lighting fixtures, e.g., the capital cost of installing task lighting systems and cost of individual fixtures for each task area. It is not currently feasible to estimate the costs associated with implementation since there are numerous ways in which task lighting can be accomplished.

Employment

Employment in two sectors will be impacted by the implementation of task lighting. Employment in the public sector will increase somewhat as local governments hire personnel to enforce task lighting codes. There could also be some job stimulation in subsectors of the lighting industry; however, these impacts were not estimated.

G. TOTAL ENERGY SYSTEMS

1. Maximum Energy Savings

Because of the complexity of Total Energy as a component of the commercial energy system, the process by which energy savings were estimated is correspondingly more complex than those used for the other commercial energy conservation measures. Total Energy Systems do not result in a decrease in the amount of electrical energy required on site, nor do they result in a decrease in the quantity of fuel purchased for on-site use. In fact, there is an increase in the amount of fuel purchased for on-site use. They do, however, result in a decrease in the fuel requirements at the central power plant. These decreases in fuel demand at the power plant compensate for increased fossil fuel consumption on-site.

The net energy savings resulting from the use of total energy systems is then computed as equal to the waste heat recovered plus the amount of fossil fuel required to generate an equivalent amount of electricity at the central power plants less fossil fuel purchased for on-site use. The use of an on-site power generation system does eliminate power losses incurred in the distribution of electric power, but the use of a central system does incur additional on-site thermal distribution losses not incurred with unitary systems.

Because energy savings are a function of electric energy demand, the net savings are shown as thermal savings as a percent of electrical demand.[1]

Consider the energy savings available in Class 1, stores and offices, as an example. In 1970, this class required 150 billion kilowatt hours, or 45% of the commercial sector's electric energy. It is anticipated that Total Energy Systems can satisfy 8% of the electrical demand for a total saving of 12 billion kilowatt hours, or 40.9 trillion BTU_e. Total Energy Systems in offices and stores operate at an approximate electircal generation efficiency of 26%. Therefore, these 40.19×10^{12} BTU_e require 157.3×10^{12} BTU_t for generation.

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[1] As estimated in Speilvogel, 1974.

This results in 116.4 x 10^{12} BTU_t of waste heat, of which 30% or 34.9 x 10^{12} BTU_t is recoverable. As a annual efficiency of 70%, this thermal energy would require the purchase of 44.9 x 10^{12} BTU of fossil fuels. The fossil fuel balance on-site is a minus 107.4 x 10^{12} BTU_t made up of an additional fossil fuel purchase of 157.3 x 10^{12} BTU_t less 49.9 x 10^{12} BTU_t recovered. However, this 12 billion KWh would require use of 125.8 x $10^{12}$$BTU_t$ of fossil fuel at a central power plant. The net saving in fossil fuel is then 125.8 trillion BTU_t at the power plant, less the 107.4 x 10^{12} BTU_t increase in on-site consumption for the Total Energy System. This results in a savings of 13.4 x 10^{12} BTU_t.

These calculations were repeated for each class as shown in Figure IV-14 and show that for a demand of 337 billion KWh, 52.7 trillion BTU_t are conserved. Converting KWh to BTU, this amounts to 52.7 trillion BTU_t savings out of 3530 BTU_t of electricity, or approximately 1.5% energy savings. The calculated maximum savings are shown in Figure IV-3. In general, energy savings resulting from the use of Total Energy Systems are somewhat less than what one would intuitively expect. There are many reasons for this of which a few of the more significant are listed below.

- Total Energy Systems generally operate at part loads and therefore not at peak efficiency. Central power plant operation allows the shifting of generation so that on line equipment is generally operating at peak efficiency.
- Peak thermal energy demand and peak electrical energy demands do not generally have coincide, resulting in a need for supplemental fossil fuels or a need to reject otherwise recoverable thermal energy.
- Cooling with Total Energy Systems is generally accomplished with absorption chillers augmented by more efficient centrigufal chillers. Conventional systems reley on the use of more efficient centrifugal chillers.
- Centralized Total Energy Systems require additional thermal energy to make up for thermal distributional losses not incurred with imitary systems.

While the use of Total Energy Systems does produce energy savings in some segments of the commercial sector, these savings are generally of the order of 1% of electric demand. Considering the uncertainty associated with analyses of performance of large aggregations of buildings, independent of climatological considerations, no broad recommendations for use of Total Energy Systems as an energy conservation measure can be made.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

The estimates of maximum energy savings possible through the promotion of total and selective energy systems in commerical buildings was reduced to one percent implementation in 1977, 15 percent in 1980, 25 percent in 1985 and 35 percent in 1990. Approximately 25 x 10^{12} BTU_t of energy savings potential between 1977 and 1990 would be realized. These reductions were based on the following assumptions:

FIGURE IV-14

CALCULATION OF MAXIMUM ENERGY SAVINGS RESULTING FROM THE UTILIZATION OF TOTAL ENERGY SYSTEMS IN THE COMMERCIAL SECTOR

CLASS	1970 ELECTRICITY CONSUMPTION[1]		POTENTIAL SATURATION	REDUCTION ON PURCHASE OF ELECTRICITY		SEASONAL ELECTRICAL EFFICIENCY OF TOTAL ENERGY SYSTEMS[2]	ENERGY REQUIRED TO GENERATE ELECTRICITY	WASTE HEAT	USABLE WASTE HEAT	USABLE WASTE HEAT	EQUIVALENT THERMAL ENERGY REQUIRED ON-SITE[3]	EQUIVALENT THERMAL ENERGY REQUIRED AT CENTRAL POWER PLANTS[4]	ENERGY[5] SAVINGS	ENERGY SAVINGS AS PERCENTAGE OF ELECTRICIT CONSUMPTIC
	(10^9 KWH)	(10^{12} BTU$_e$)	Percent	(10^9 KWH)	(10^{12} BTU$_e$)	Percent	(10^{12} BTU)	(10^{12} BTU)	Percent	(10^{12} BTU)	(10^{12} BTU)	(10^{12} BTU)	(10^{12} BTU)	
Stores & Offices	150	1572	8	12.0	40.9	26	157.3	116.4	30	34.9	49.9	125.8	18.4	1.2%
Religious	14	146	0	0	0	18	0	0	10	0	0	0	0	0
Educational	50	524	10	5.0	17.1	26	65.8	48.7	20	9.7	13.9	52.4	0.5	0.1%
Hospital & Industrial	45	471	20	9.0	30.7	29	105.9	75.2	35	26.3	37.6	94.2	25.9	5.5%
Military	16	167	10	1.6	5.5	27	20.4	14.9	24	3.7	5.3	16.8	1.7	1.0%
Misc.	62	650	8	5.0	17.0	27	63.0	46.0	25	11.5	16.4	52.4	5.8	0.9%
TOTAL	337	3530	9.7	32.6	111.2	-	-	-	-	-		-	52.7	1.5%

1. See Figure IV-1
2. Based on estimates by Spielvogel, L., Commercial Energy Conservation, report submitted to MATHEMATICA, 1974.
3. Based on 70% seasonal boiler efficiency.
4. Assumes a heat rate of 10.479 BTU/Kwh.
5. Equal to thermal energy saved at the centralized power plant plus the recovered heat minus fossil energy consumed onsite by the total energy system.

- According to a HUD spokesman involved in the HUD Total Energy System program,[1] currently there are approximately 600 buildings and plants operating under total energy systems. Therefore, given implementation of this measure in 1976, by 1977 somewhat less than one percent of commercial buildings would be operating under total or selective energy systems.
- An estimate of between 30 and 40 percent implementation of all commercial buildings by 1990 was given by Eugene Gore, an expert in the TES field.[2]

Both the HUD spokesman and Gore made this implementation level dependent upon several criteria. For example, at least the standard 7 percent tax credit allowed on capital investments would have to be applicable to total and selective energy system equipment. Such equipment currently does not qualify because it is considered part of the structural components of a building. The federal tax law would have to be changed to allow credit for energy conserving systems, with appropriate mechanisms for the IRS to monitor the credit.

In addition, there are attitudinal problems which have to be overcome through education: both builders and banks are very hesitant to invest in the systems because of high initial costs and unfamiliarity with the concepts, and utility companies are very opposed to them because the systems constitute competition. HUD has already begun a five-year campaign to educate savings and loan institutions and utility companies about the energy conservation advantages of TES. Thus, a governmental structure exists to deal with the public education aspects of this problem. (Gore suggested, however, that federal intervention might be necessary to induce the utilities to cooperate with TES. More than 450 court cases have been brought by utilities against total energy systems.)

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[1] Utilities Systems Research, Office of Policy Development and Research, U.S. Department of Housing and Urban Development.

[2] Eugene Gore, S.W. Brown Associates, consulting engineers, New York City.

Because of these requirements, PMM&Co. is inclined to believe that the 35 percent implementation estimate is high.

According to HUD, there would be no feasibility problems with regard to research or development; they have used ready-made components in several of their demonstration projects. HUD also indicated that current and projected manufacturing facilities for these components would be adequate for future demands for total and selective energy systems.

IMPACTS

The potential impacts associated with implementation of energy systems are minimal since only a small energy saving realization per total energy system is anticipated. In addition, most of the impacts will not be major until after 1985.

Private Consumer Cost/Savings

Reduced consumption of energy in the commercial sector as a result of total energy systems would not have a direct impact on consumers, other than passed on costs incurred by commercial enterprises. These savings have not been estimated.

Public Sector Cost/Savings

By 1990, the conservation of U.S. energy from this measure could result in a $0.71 million reduction in imports of fuel. In addition, the tax credits will impact total tax revenues.[1]

Quality of Life

There should be no significant quality of life impacts through implementation of the measure.

---

[1] Costs have not been identified.

Materials/Resources

There are no anticipated materials/resources problems associated with this measure.

Environment

Because of the low realization of energy savings, reduction in SO_2 will only be approximately 1.05×10^6 by 1990. As a proportion of commercial energy sources and total energy sources, the reduction impact is minimal at 3.0 percent and .07 percent respectively. Correspondingly there will be little impact on other pollutants.

Private Industry Cost/Savings

As with most of the previous commercial energy conservation measures, the primary impact of this measure would be reduced energy sales. These have been calculated to be a reduction of $314 million in heating oil, natural gas, and electric utilities by 1990.

There would be a major impact in the industries concerned with manufacture and installation of energy systems in terms of new sales. Conversely, there would be an added capital cost for new buildings construction.[1]

Employment

No employment impacts were identified for this measure.

Figure IV-15 shows a summary of impacts.

---

[1] Costs have not been identified.

FIGURE IV-15

TOTAL AND S[illegible] ENERGY SYSTEM IMPACT SUMMARY

	Annual Impact 1977	1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	39	75	236	403	2,975
2. Estimated Feasible	0.3	17	61	182	832
B. Impacts (Millions of Dollars)					
1. Private Industry					
Energy savings commercial sector	$ 1.1m	$ 72m	$ 267m	$ 670m	$ 3,620m
Construction Cost Change			Not Estimated		
2. Private Consumer			Not Estimated		
3. Public Sector					
Government			Insufficient Data		
Balance of Payments	$ .03m	$ 1.7m	$ 5.5m	$ 16.7m	$ 86.0m
4. Employment (Jobs)					
5. Environment (Percent Reduction)					
SO_2 Reduction	0	.01%	.19%	.042%	

H. USE OF SOLAR ENERGY AND/OR HEAT PUMPS

1. Maximum Energy Savings

Solar heating systems are beginning to become economically attractive in the commercial sector.[1] Heat pumps have been used for years in commercial buildings, and their popularity is increasing rapidly. When combined, the solar heating system and the heat pump can enhance each other's performance, and contribute towards reducing the amount of thermal energy required for buildings.

The application of solar/heat pump technology to commercial buildings is similar to residential applications (See Chapter II Section G) with few exceptions. The technology of the components and systems are discussed in Appendix B. The range of possible applications include:

- Water Source Heat Pump
- Solar Assisted Systems
- Full Solar

The opportunity for energy conservation within commercial buildings (office buildings, schools, etc.) is significant since even in the winter months air conditioning for internal spaces may be necessary for thermal comfort. It is significant to note that the ratio of air conditioning to heating requirements ranges from .1 to 1.0 through the winter months from November to March for most reasonably sized structures.

Water Source Heat Pump

Although there are a number of ways that the thermal energy from the air conditioning system may be recovered, one of the most efficient and interesting is the use of the water source heat pump. Characteristics of the heat pump are presented in Appendix B. They generally apply to the water source heat pump with the exception that the associated temperature drops in the heat exchangers are significantly less than for the air source and, therefore, the overal COP for the water source heat pump approaches 3.0 to 3.2 with the eventual possibility of approaching 4.0.

---

[1] University of Maryland, 1973 and NSF/NASA, 1972.

A water source heat pump system with energy recovery[1] from air conditioning is shown in Figure IV-16. In this system reverse cycle heat pumps are used such that in the heating mode energy is removed from the loop. When they are operating in the air conditioning mode they are adding energy to the loop. When there is a balance, the loop operates between 60° and 90°F; if there is an excess of heating requirements, the electric heaters may come on; if there is an excess of air conditioning, the loop will heat up beyond 90°F and the heat rejectors must be used. There is no thermal storage system other than the thermal capacity of the water in the piping system.

Solar Assisted Systems

The solar assisted systems are identical to those described in Chapter II Section G:

1) Conventional Heating System with Solar Supplement.
2) Solar Assisted Water Source Heat Pump (with energy recovery from the air condition requirements from internal spaces or other sources of thermal energy).

Full Solar

The full solar system for a very large commercial structure requires a significant amount of collector area. Any solar system will have some type of auxiliary or back up, but the full solar system will be similar to those described in Chapter II.

Summary

° In general, the most likely solar assist system will be the solar assisted heat pump. The system has the great advantage of using the commercially available water loop/water source heat

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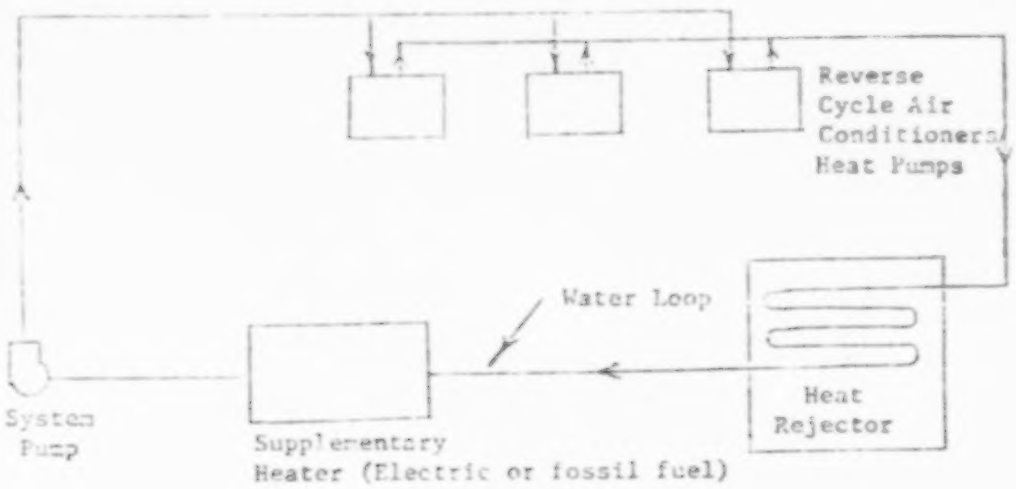
[1] From Brown and Hamel, 1974

FIGURE IV-16

WATER SOURCE HEAT PUMP SYSTEM


Reverse
Cycle Air
Conditioners/
Heat Pumps
Water Loop
Heat
Rejector
System
Pump
Supplementary
Heater (Electric or fossil fuel)

pump as the base system and only requiring solar panels and some storage as additional add-on components to the system. The energy saving and economics of such a system can be quite attractive.[1]

- ° The water loop heat pump appears to be quite attractive, is now commercially available, and should begin to have an immediate impact.
- ° The solar assisted/water loop heat pump system appears to be quite attractive as solar assist to the commercially available water loop systems.
- ° The solar system seems to be not practical until collector costs approach $\$2/\mathrm{ft}^2$, even then, the solar panel-building integration problem could be serious.

The calculation of the percentaage energy savings is shown in Figure IV-17.

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

The reduction in maximum possible savings due to the commercial use of solar assisted heat pumps was based on the market penetration proposed by Hamel and Brown: zero implementation in 1977; 3 percent in 1980; 6 percent in 1985; and 10 percent in 1990.[2] This market penetration schedule would result in approximately 5.2 percent realization of total energy saving potential between 1977 and 1990 or a total savings of 6.23×10^{12} BTUs.

These percentages were based upon the assumption of the solar assisted heat pump's appeal in a free market without any added incentives, given that significant development and field testing would be necessary first and that the initial cost of solar devices was high.[3]

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[1] Univ. of Pennsylvania, 1973.

[2] Brown and Hamel, 1974.

[3] *Ibid*.

FIGURE IV-17

CALCULATION OF THE PERCENTAGE ENERGY SAVINGS IN THE COMMERCIAL SECTOR RESULTING FROM THE IMPLEMENTATION OF ENERGY CONSERVATION MEASURES

MEASURE: USE OF SOLAR/HEAT PUMPS

ELECTRICITY

CLASS	1970 CONSUMPTION[1] (Billion KWH)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Billion KWH)	%[3]	AMOUNT (Billion KWH)	
1. Stores & Offices	150	40	60	-20	12.0	-8.0
2. Religious	14	10	1.4	-10	.14	-1.0
3. Educational	50	20	10.0	-15	1.5	-3.0
4. Hospital and Institutional	45	10	4.5	-30	1.35	-3.0
5. Military	16	20	3.2	-20	.64	-4.0
6. Miscellaneous	62	40	24.8	-20	4.96	-8.0
TOTAL	337	30.8	103.9	-19.8	20.6	-6.1

FOSSIL FUEL HEAT

CLASS	1970 CONSUMPTION[1] (Trillion BTU)	AFFECTED BY ENERGY CONSERVATION MEASURE		ENERGY SAVINGS[2]		ENERGY SAVINGS AS A PERCENT OF TOTAL CONSUMPTION
		%[3]	AMOUNT (Trillion BTU)	%[3]	AMOUNT (Trillion BTU)	
1. Stores & Offices	1138	40	455.2	80	364.2	32.0
2. Religious	180	10	18.0	90	16.2	9.0
3. Educational	756	20	151.2	75	113.4	15.0
4. Hospital and Institutional	375	10	37.5	35	13.1	3.5
5. Military	237	20	47.4	60	28.4	12.0
6. Miscellaneous	615	40	246.0	70	172.2	28.0
TOTAL	3301	28.9	955.3	74.1	707.5	21.4

1. Source: See Figure IV-1.
2. Applied only to that portion of the energy consumption affected by the conservation measure.
3. Based on Spielvogel, L., Commercial Energy Conservation, report submitted to MATHEMATICA, Inc., 1974.

The suggested implementation strategy of allowing a tax credit (similar to the 7 percent capital investment) would probably not increase the suggested percentages appreciably, although lower operating costs might have a positive impact on market penetration. No quantifiable data existed on the possible increase due to a tax credit.

IMPACTS

Private Consumer Cost/Savings

Reduced commercial use of conventional energy sources as a result of solar systems would have no direct impact on consumers.

Public Sector Cost/Savings

The U.S. balance of payments posture will be improved by the reduction of imported energy. This is estimated to be approximately $64 million by 1990.

Materials/Resources

There are no anticipated materials/resources problems associated with this measure.

Quality of Life

There should be no significant quality of life impacts through implementation of this measure.

Environment

Extremely low implementation rates severely limit the pollution reduction potential of solar assisted heat pumps in the commercial sector. By 1990, approximately 14.5×10^6 lbs. of SO_2 generation per year would be avoided. However, this only accounts for only about 0.02 percent of total sulfur dioxide emissions.

Private Industry Cost/Savings

The reduced energy consumption of heating oil, natural gas, and electricity as a result of solar heat pumps in the commercial sector would produce a cost savings of about $2.7 billion by 1990.

Other costs, which could not be calculated because of insufficient data on the commercial application of solar systems (most research appears to have centered on residential applications), are the capital costs of the solar system. Most data gives some indication that the first cost of a solar system is high. However, it is probable that capital cost could be offset substantially by operating savings and the proposed tax incentive.

Employment

No employment impacts were identified for this measure although some new jobs in the manufacture, sale, and service of solar systems might be created.

Figure IV-18 shows a summary of impacts.

FIGURE IV-1[illegible]

SOLAR-ASSISTED HEAT PUMPS IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	105	288	712	1,268	8,726
2. Estimated Feasible	0	9	43	127	623
B. Impacts (Millions of Dollars)					
1. Private Industry					
Commercial Energy Savings	0	$39m	$188m	$557m	$2,732m
Incremental Capital Costs		Insufficient Data			
2. Private Consumer		Not Estimated			
3. Public Sector					
Government		Insufficient Data			
Balance of Payments	0	$0.9m	$4m	$13m	$64m
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)					
SO_2 Reduction	0	.018%		.019%	

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V. ENERGY CONSERVATION IN THE TRANSPORTATION SECTOR

A. INTRODUCTION

The transportation sector, which accounts for 25% of U.S. energy consumption, is a particularly heavy user of petroleum based fuels.[1] Fully 60%[2] of U.S. petroleum consumption is accounted for by transportation. This represents 95% of transportation energy.[3] Total transportation energy is growing at 4.1% a year.[4] This combination of the heavy use of petroleum and the strong growth rate combine to make energy conservation especially important to the United States.

The transportation sector can be divided into two distinct areas: passenger transportation and freight transportation. Within both of these areas, a variety of modes of transportation are used for the movement of goods or people. Each of these modes has its own patterns of energy use and environmental impact as well as a supporting economic structure. The various modes within an area relate to each other primarily as competitors. Between areas they are related by the use of common facilities or equipment.

A particularly important characteristic of a mode is its energy intensiveness, which is the average amount of energy required to generate a "unit of traffic ". More specifically, for freight transportation, the unit of traffic is the ton-mile (TM), which is the movement of one ton of freight payload the distance of one mile. Correspondingly, the unit of traffic for passenger transportation is the passenger-mile (PM), which is the movement of one passenger the distance of one mile. Thus, energy intensiveness is the average energy usually expressed in British Thermal Units per ton or passenger (BTU/TM or BTU/PM). The most energy intensive modes are airplane and motor vehicle transport of both freight and passengers.

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[1] RAND, 1973.

[2] Statistics, 1973.

[3] RAND, 1973.

[4] Ibid.

Energy conservation measures in the transportation sector generally fall into three categories:

(1) Decreasing total traffic
(2) Decreasing the energy intensiveness of a mode
(3) Shifting traffic from modes of high energy intensity to alternative modes of lower energy intensity.

In this report, conservation measures were chosen which would fall under categories (2) and (3) above, because it was believed that large energy savings could be realized by increases in efficiency without the sacrifices, economic and othewise, implied by decreasing total traffic. It should be realized, though, that the practical implementation of the proposed measures may result in decreases (or increases) in total traffic. However, for purposes of calculation of maximum technically feasibly energy savings, it was assumed that total traffic would remain the same with measure implementation.

Seven measures were chosen for analysis in this study. These are listed in Figure V-1. The distribution of energy consumption of the transportation sector in 1970 is shown in Figure V-2. The heavy dominance of road based transportation in energy consumption is clearly evident in this figure. The maximum technologically feasible savings from each measure are shown in Figure V-3. Included is the estimated achievable savings resulting from the corresponding implementation option.

Figure V-1

ENERGY CONSERVATION MEASURES - TRANSPORTATION SECTOR

SERIAL NO.	CONSERVATION MEASURE	IMPLEMENTATION STRATEGY
T-1	Increased use of car pools	giving carpools privileges not afforded to single car commuting, such as lower cost and preferential parking, use of bus lanes (3 or 4 riders, required per car), and elimination or reduction of bridge or tunnel tolls.
T-2	Increasing automobile efficiency	a) voluntary increased maintenance; b) voluntary tune-ups; c) mandated use of radial tires; d) mandated energy efficient aerodynamic design of automotive vehicles; and e) mandated federal engine efficiency standards per weight of vehicle.
T-3	Increasing use of piggyback and containerization for intercity freight	encourage highway users to utilize the more fuel-efficient alternatives of container or trailer on flat car (COFC or TOFC), through regulatory avenues, legislated economic incentives, and voluntary public cooperation.
T-4	Modal shifts in intercity passenger transportation	increasing the frequency, range, and quality of service through legislative change and economic incentives.
T-5	Increased use of bus transit	better and faster service and economic incentives including: greater operating frequency and area coverage; improved routing to meet commuter needs; use of exclusive bus lanes; subsidized transit fares; and reduction in downtown parking through higher parking taxes.
T-6	Improved scheduling and load factors for air transportation	Not considered.
T-7	Reduced speed limits on highways	Not considered.

Figure V-2

ENERGY CONSUMPTION IN THE TRANSPORTATION SECTOR
(1970)

TYPE	MODE	1970 (10^{12} BTU)
Passenger	Automobile	
	Intercity	5,695
	Other	3,235
	Total	8,930
	Railroad	32
	Bus	
	Intercity	40
	Intracity	45
	Airplane	1,251
	Total	10,298
Freight	Rail	
	Intercity	519
	Trucking	
	Intercity	1,175
	Total	1,694
Accounted for Energy	All above	11,992
Energy not Accounted for	Other	4,487
Total Energy	All Transportation	16,126

Figure V-3

SUMMARY OF ENERGY SAVINGS - TRANSPORTATION SECTOR

(Trillion BTU's)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Increased Car Pooling	2,448	2,586	2,904	3,408	840	885	975	1,167
Increased Auto Efficiency	1,175	1,895	2,830	3,464	0	1,690	2,790	3,464
Increased TOFC Use	239	255	282	297	2.4	5.1	11.3	17.8
Intercity Modal Shifts	121	248	414	575	121	248	414	575
Increased Bus Transit	2,618	2,739	3,000	3,480	25	60	138	263
Improved Airplane Scheduling & Load Factors	250	662	1,286	2,208	NE	NE	NE	NE
Reduced Highway Speed Limits	928	1,057	1,312	1,623	NE	NE	NE	NE

NE - Not Evaluated

B. INCREASED USE OF CARPOOLS

1. Maximum Energy Savings

General Discussion

The increased use of carpooling is probably one of the most publicized of all energy conservation measures. Not only is promotional effort being aimed at auto drivers, but further effort is being planned by the Federal Highway Administration (FHWA) which will be aimed at employers as well.[1] An effective employer run program of carpool incentives should include five basic components; top management support, vigorous promotion, employee incentives, matching programs and continuing service.[2] The FHWA provides information for setting up a matching service in their Carpool and Buspool Matching Guide.[3] Another method which has been proposed as a carpool incentive is reserved highway lanes for buses and carpools.[4] This increased peak hour auto occupancy by 8% over the San Francisco-Oakland Bay Bridge during an experiement tried there.[5]

In addition to being heralded as a means of energy conservation, carpooling is seen as a means of reducing traffic congestion, air pollution, noise pollution, and commuting costs.[6] The basic idea is quite simple; get people to ride together in one car and vehicle trips are reduced. This results in less gasoline consumption, traffic congestion, automobile noise, and pollutant emissions.

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[1] Pratch, 1974b

[2] Ibid

[3] FHWA, 1973

[4] Capelle et al, 1971

[5] California, 1973

[6] For example, Pratch, 1974a

This study evaluates the reduction of energy requirements due to decreased vehicle miles traveled. Some further energy savings may result from improved traffic flow,[1,2] but the issues involved are complex and are only briefly treated here. It is, however, expected that these energy savings will be considerably smaller in magnitude than those arising from decreased vehicle miles.

Another side effect that may have significant import is that automobiles left at home by carpool participants may be used by spouses and teenagers. To the extent that these trips would not have been taken otherwise, this will decrease the effectiveness of carpooling. No estimate is made of the magnitude of this effect.

The continued use of passenger automobiles for transportation is the most commonly discussed means of carpooling, but there are other alternatives available. For instance, an employer-run van pool program has been successful in the Minnesota Mining and Manufacturing Company in St. Paul, Minnesota[3]. This program involves the purchase of vans by an employing organization which then allows its employees to have complete use of them for commuting purposes. Advantages for the employer are decreased congestion of installations and reduced demand for parking which allows the use of former parking areas for other purposes. Another technique is the use of rider controlled buses in "bus pools". This has been successful in a number of instances,[4] notably for the residents of Columbia, Maryland and Peston, Virginia. The common denominator of these different "pool" methods is that the energy savings arise primarily from increased vehicle occupancy.

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[1] Highway Users Federation, 1973

[2] Pratch, 1974c

[3] Owens and Severs, 1974

[4] Pratch, 1974

Considering the many and varied purposes of automobile trips, it is apparent that in order to significantly increase average vehicle occupancy of unrelated persons, the trips to be "pooled" must be taken regularly in terms of both time and route. The one type of travel that meets this criteria is commuting to work. This accounts for 33.7%[1] of travel in personal automobiles. The distribution of vehicle miles by type of trip for commercially owned autos is not known from any published data, so an assumption was made for simplicity of calculation that, of these vehicle miles, 33.7% is also for work commuting purposes and that these are also suitable for carpooling. At any rate, the number of commercially owned cars is small compared to personally owned cars.

Current average occupancy per vehicle mile is 1.63[2] for home-to-work trips. However, average occupancy per trip is 1.4. The difference arises from longer trips having a greater occupancy.[3,4] Figure V-4 illustrates further data on automobile occupancy for home to work trips. It shows that 47.5% of auto commuters travel by carpool and 54.3% go to work alone. The trip weighted average number of passengers in a carpool auto is 2.52

In the study completed by Zevin,[5] it was found that a variable which had a significant impact on work commuting trip occupancy was the availability of parking. As parking spaces became scarce in an area, auto occupancy for those working in the area rose. He also found that employees of larger organizations tend to drive to work in autos with higher occupancy levels. The distance of commuting also has a large impact on vehicle occupancy. For instance, home to work and return trips under 5 miles average 1.3 to 1.4 occupants, while those over twenty miles average about 1.6 occupants.[6]

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[1] FHWA, 1972,

[2] Ibid

[3] Zevin, 1972

[4] FHWA, 1972

[5] Zevin, 1972

[6] FHWA, 1972

FIGURE V-4

PERCENT OF AUTO TRIPS BY NUMBER OF OCCUPANTS
(Communter Trips)

No. of Occupants	% of Total Trips	% of Carpool Trips
1	74.5	-
2	17.6	70.6
3	4.1	16.6
4	1.6	6.4
5	1.0	4.0
6	0.4	1.6
7	0.1	0.4
8	0.1	0.4
N/A	.6	
	100.0	100.0

45.7% go by multi-person car

56.3% go alone

Average number in carpool weighted by trips 2.52

Source: Federal Highway Administration, National Personal Transportation Study, 1972.

Assumptions

In order to calculate the amount of energy potentially saved by carpools, the following assumptions are made:

- Currently home to work travel comprises 33.7% of all base case auto vehicle miles of travel.[1] This relationship is assumed to continue in the future. These home-to-work automobile trips form the potential reservoir of trips susceptible to carpooling.
- Only the effects from reduced number of vehicle miles are considered. The effects of reduced congestion are assumed to be small.
- Carpools reduce vehicle miles of travel while passenger miles stay about constant, except to the extent that there is a 5% increase per passenger in both passenger and vehicle miles due to extra travel to pick up passengers.[2]
- Only home-to-work travel at all hours is considered as amenable to carpooling as it is the only regularly repeatable and "plannable" category of travel in which unrelated people can be combined.
- Average BTU/vehicle miles for home to work trips is different from that for total auto travel because of the different distribution in trip lengths. The average of this distribution will increase one-half percent per year as people continue to move to suburbs during the 1970's ending in 1980. The average BTU/vehicle mile for home to work trips is calculated in Figure V-5.

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[1] FHWA, 1972, Vol. 1
[2] Highway User's Federation Estimate

- Vehicle efficiency improves in the base case as determined in the measure on fuel economy. For carpools, it will increase proportionately, thus reducing the potential impact of carpooling.
- BTU/vehicle mile are calculated for different length trips as determined by Hirst.[1] (See Figure V-5)
- No adjustment is made for the added weight of extra passengers in each car, although in practice, this may tend to slightly reduce the effectiveness of carpooling.

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[1] Hirst, 1974

FIGURE V-5

FUEL USE IN HOME TO WORK TRIPS

(1969)

DISTANCE Miles	AVERAGE[1] OCCUPANCY	PERCENT OF[1] VEHICLE TRIPS	PERCENT OF[1] VEHICLE MILES	BTU/VM[2]	TOTAL TRIP[3] FUEL USE (BTU)
L.T. 1/2	1.3	5.5	0	18,000	9,000
1	1.4	11.5	1.2	18,000	18,000
2	1.4	10.3	2.2	14,600	32,600
3	1.3	9.7	3.1	13,400	46,000
4	1.3	6.4	2.7	12,500	58,500
5	1.4	8.8	4.7	12,000	70,500
6-10	1.4	20.4	17.9	11,000	81,500
11-15	1.4	11.1	15.8	10,400	91,900
16-20	1.5	6.8	13.2	9,900	101,800
21-30	1.7	5.8	15.9	9,400	111,200
31-40	1.5	2.1	8.4	8,100	119,300
41-50	1.6	0.9	4.4	8,100	127,400
51-99	1.6	0.5	3.6	8,100	135,500
100 -	1.6	0.2	6.9	8,100	143,600

Average occupancy weighted by trips = 1.40

Average Occupancy weighted by vehicle miles = 1.63

Average BTU/VM is 1970 = 11,462 (11.9 mpg)

Sources:

1 Federal Highway Administration, National Personal Transportation Study, 1972.

2 Eric Hirst Direct and Indirect Energy Requirements for Automobiles, 1974

3 Total trip fuel use = $\sum_{i}(\text{BTU}/\text{VM}_i)$ percent VM_i where i = trip distance.

Congestion

Motor vehicle congestion produces several adverse effects. These include increased fuel consumption, traffic accidents and vehicle emissions. Carpooling, which should be heaviest at times of rush hour peak congestion, should therefore be an effective means of reducing the deleterious effects of congestion.

According to the Highway Users Federation,[1,2] congested stop and go traffic can greatly reduce average speed and, in some cases, double energy consumption. Furthermore, high densitites of traffic result in increased number of accidents. A recent study by EPA, showed sharp increases in hydrocarbon and carbon monoxide emissions with decreased vehicle route speed.[3]

Calculation of Energy Savings

The calculation of the energy savings at different occupancy levels is given by the following equation. The detailed derivation of this equation is given in Appendix D.

$$f = 1 - \frac{x_o}{x_c} \left(1 + .05 \left(x_c - x_o\right)\right)$$

Where:

f = fraction of original energy saved

x_c = changed occupancy rate per vehicle mile

x_o = current occupancy rate per vehicle mile = 1.63[4]

Figure V-6 represents a forecast of base case home-to-work vehicle miles and fuel consumption assuming the occupancy level remains the same. Figure V-7 shows the potential energy savings (or losses) from changed occupancy levels.

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[1] Rankin, 1973.

[2] McClure, 1973.

[3] EPA, 1973b.

[4] FHWA, 1972.

FIGURE V-6

CARPOOL BASE CASE FORECAST

YEAR	TOTAL AUTO VEHICLE MILES (10^9)	HOME TO WORK VEHICLE MILES (10^9)	RATIO OF MPG IN 1970 TO MPG IN YEAR	BTU/VEHICLE MILE	TOTAL ENERGY (10^{12} BTU)
1977	1113	375	.951	10,900	4088
1980	1185	399	.941	10,786	4304
1985	1387	467	.904	10,362	4839
1990	1651	556	.891	10,212	5678

Source: **MATHEMATICA** estimate based on FHWA, National Personal Transportation Study, 1972 and Chase Econometrics, Automobile Gasoline Consumption Forecasts, 1974.

FIGURE V-7

CARPOOL ENERGY SAVINGS FOR DIFFERENT OCCUPANCY LEVELS

(trillion BTU)

AVERAGE PER MILE OCCUPANCY	FRACTIONAL SAVINGS	YEAR			
		1977	1980	1985	1990
1.00	-.5786	-2365	-2490	-2708	-3285
1.63	0	0	0	0	0
1.70	.0378	155	162	183	215
1.80	.0867	354	373	420	492
1.90	.1305	533	562	631	741
2.00	.1699	695	731	822	965
2.10	.2056	840	885	995	1167
2.20	.2380	973	1024	1152	1351
2.30	.2676	1094	1152	1295	1519
2.40	.2947	1205	1268	1426	1673
2.50	.3196	1307	1376	1547	1815
MAXIMUM FEASIBLE CASE 4.7	.6000	2448	2586	2904	3408
BASE CASE ENERGY CONSUMPTION (OCCUPANCY = 1.63)		4088	4304	4839	5678

The estimation of a maximum technologically feasible energy savings is somewhat arbitrary, as it depends on how many people can be packed into automobiles.

A per trip average occupancy of four would seem a reasonable estimate. Assuming that the ratio of vehicle mile weighted occupancy to trip weighted occupancy remains constant for all trip weighted occupancies, a maximum vehicle weighted occupancy of approximately 4.7 is determined. This results in a 60% savings in home-to-work commuter auto energy. Projected savings in trillion BTUs are 2448 in 1977, 2586 in 1980, 2904 in 1985, and 3408 in 1990. Anticipated practical energy savings would undoubtedly be not nearly as high.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

To estimate carpooling impact, the following implementation strategies were assumed:

reduced parking cost;
preferential parking;
exclusive commuting lanes; and
bridge/tunnel toll exemption

Since approximately 34% of personal automobile travel consists of cummuting to and from work, and the commuting automobile averages only 1.3 to 1.4 people per trip, an increase of 1.0 persons per vehicle trip could substantially reduce automobile use for commuting. Recent data from the National Personal Transportation Study (1972) indicate that 45.7% of the commuting automobile trips are made with more than one occupant and 56.3% of commuting trips are made alone. The latent potential (56.3%) to increase the number of persons per vehicle is quite high.

The ability to realize the latent carpooling potential is complicated by (1) the ability to put the above implementation strategies into effect; (2) the effectiveness of the strategies; and (3) the ability of the commuter to select alternative commuting options (e.g., mass transit). Alternative options may become critical when implementation strategies are negative (e.g., parking surcharge) or when positive incentives for mass transit are in force. However, the reduction of single-person automobile commuting trips, whether by means of carpooling or by diversion to mass transit, still results in energy savings.

The estimate of feasible energy savings attainable through increased carpooling, using the above implementation strategies, is based upon the following assumptions:

- a parking surcharge of $2.50 for single person per vehicle work trips;
- a parking surcharge of $1.25 for a two person per vehicle work trips;
- no parking surcharge for three or more persons per vehicle work trips;
- improved mass/bus transit
- toll exemptions for carpools; and
- reserved access lanes for carpools.

Within this scenario, and based upon a simulated modal split analysis[1], average work trip vehicle occupancy was estimated to increase from approximately 1.2 (base case) to 1.6[2] in a major urban area. The above scenario analysis suggests that an increase of 0.4 persons per vehicle for work trips is attainable. The incremental increase in auto occupancy suggested by the above values was used to estimate potential energy savings. Assuming 1.63 occupancy per mile equals zero savings (base case); the increase in average occupancy suggested by the San Diego analysis would result in a 2.10 occupancy per mile or approximately 21% energy savings. The estimated energy savings based upon this relationship are shown in Figure V- 8.

It should also be kept in mind that carpooling is very much subject to other urban transportation developments. In particular, future carpooling will be affected by (1) potential completion of the urban radial freeway system, and (2) continued upgrading and development of new mass transit service. The impact of these factors has not been incorporated into this analysis.

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[1] PMM, 1973.

[2] Estimated occupancy in San Diego area.

FIGURE [illegible]

INCREASED CARPOOLING IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	2448	2586	2904	3408	39,573
2. Estimated Feasible	840	885	995	1167	13,696
B. Impacts (Millions of Dollars)					
1. Private Industry			Not Estimated		
2. Private Consumer					
Savings	$5411m	$5746m	$6734m	$8015m	$88,664m
3. Public Sector					
Government gasoline tax loss	($ 680 m.)	($ 717 m.)	($ 802 m.)	($ 934 m.)	($11038 m.)
Balance of Payments	$ 268 m.	$ 283 m.	$ 318 m.	$ 373 m.	$4383 m.
4. Employment (Jobs)			Not Estimated		
5. Environment (Percent Reduction)					
CO Reduction	.380%	.510%	1.1%	1.38%	
HC Reduction	.297%	.513%	.524%	.662%	

IMPACTS

Private Consumer

Commuters continuing to travel alone, given the implementation strategies, would be faced with a substantially increased cost. Assuming an average 13-mile round trip to and from work and a $2.50 parking surcharge, the added cost per vehicle mile would be almost $0.20. On the other hand, commuters joining carpools will experience significant savings due to a reduction in vehicle use. Assuming $.06 cost per carpool vehicle mile, direct cost savings are estimated as follows:

Year	Base Level Commuter Vehicle Mileage (miles x 10^9)	Estimated Commuter Vehicle Miles Reduction (miles x 10^9)	Estimated $ Savings ($ x 10^6)
1977	375	77.3	4,638
1980	399	82.1	4,926
1985	467	96.2	5,772
1990	556	114.5	6,870

If it is further assumed that the capital cost per commuter vehicle mile is approximately $.01, then capital cost savings would be equal to reduced commuter vehilce mile times $.01.

Under this assumption, the potential capital cost savings are estimated as follows:

Year	Capital Cost Savings (Millions)
1977	$ 773
1980	821
1985	962
1990	1,145

The total private consumer cost savings are then the sum of estimated milege cost savings and the capital cost savings.

Public Sector

Major government impacts would be added revenues from the parking surcharge (or cost for the parking subsidy), added cost for exclusive access lanes, and added cost for a toll road/bridge/tunnel subsidy. In addition, direct tax losses would result from decreased sales of gasoline. The tax loss, assuming $.11 per gallon, would total $11,038 million between 1977 and 1990.

Revenues associated with the surcharge plan (or parking subsidy costs), toll subsidy revenue loss, and special access costs have not been estimated. Reduced sales in gasoline would have direct impact on import requirements, estimated at $4.4 billion between 1977 and 1990.

Scarce Materials and Resources

No significant impacts on scarce resources are anticipated from implementation of this carpooling measure, as it relates to factors well within the scope of present technological capabilitie

Quality of Life

There are negative attitudinal factors related to carpooling; otherwise strong incentives, such as raised parking rates, would not be necessary to encourage people to participate. Carpooling requires a relatively rigid schedule for users and correspondingly reduces individual flexibility. In addition, individual carpooling schedule reliability depends on each person in the carpool.

Increased use of carpools would offer the positive convenience impacts associated with increased mass transit use and eliminate some of the negative ones. Like increased transit use, this measure can reduce or eliminate driving anxiety and enhance car safety because of reduced deterioration through lower mileage accumulation. Unlike mass transit, however, carpooling does not entail annoying and time-consuming transfers and waits at unprotected transit stops.

Quality-of-life impacts of carpooling are important; whether or not they are overall positive or negative depends on the individual case.

Environment

Increased carpooling can result in decreased total carbon monoxide emissions of over 1% by 1990. Similarly, the percentage of reduction in total hydrocarbon (HC) emissions possible, due to this measure, could be as high as 0.7% by 1990. As was the case in increased urban bus transit, the emission reductions cited will be in urban areas and will directly contribute to the attainment and maintenance of ambient air quality standards in the most polluted sections of the country.

Traffic congestion, as well as noise, can be reduced significantly through carpooling. Commuter traffic congestion could be reduced by approximately 30% under the scenario presented in the previous pages, since peak hour travel is directly reduced by commuter carpooling.

Increased carpooling would help reduce pressure to build parking facilities and new highways, and thus would have a beneficial land-use impact.

Private Industry

The major private industry impacts would focus on the parking industry, and the automobile manufacturing, sales and services industries.

The parking industry would suffer reduced levels of demand. As a result parking industry revenues would decline. With sufficient demand reduction, it is possible that--in many urban areas--some parking facilities would be forced out of business.

Demand for automobiles could be reduced as a result of (1) reduced need for a second car and (2) longer car life. In addition, automobile service industries could suffer a decrease in demand. These impacts have not been estimated.

Employment

Increased carpooling is not likely to increase unemployment except in areas such as parking lots and possibly gasoline/oil industries. On the other hand, because carpooling makes more efficient use of resources and increases productivity of fuel and capital, it may reduce growth in the automobile sales, service, and related areas -- similar to the effects of other transportation fuel savings measures. Insufficient data preclude definitive employment impact estimates within the scope of this report.

C. IMPROVED SCHEDULING AND LOAD FACTORS FOR AIR TRANSPORTATION

1. Maximum Energy Savings

Background

Air transporation is the most energy intensive travel mode for both passengers and freight. Studies have shown that transferring freight by air requires 15 times more energy per ton mile than by trucks and 60 times that required by trains.[1] More than 5 times the energy per passenger mile is consumed by airplanes as compared with buses and 2.5 times as much as cars.[2]

Use of airplanes to transport passengers and freight has experienced rapid growth in the past decade. During 1960 and 1970 domestic passenger miles increased by 14% per year, while freight movement increased by nearly 15% per year. However, growth is expected to wane in the future due to various economic factors and growth rates are expected to level off around 6% to 7% per year.

In addition to increased demand for air transportation, a reduction in efficiency in terms of load factors (ratio of tonnage or passengers transported to capacity) has occurred in the last twenty years. From a peak passenger load factor in 1951 of slightly under 70%, a drop to a minimum of below 50% in 1971 occurred. This was a result of the various firms' efforts to be more "competitive" by providing expanded services to customers. As a result, energy consumption in aviation has grown at a faster rate than passenger miles. Under the assumption of non-implementation of conservation measures and based on past relationships to growth in passenger miles, one might expect a maximum annual growth rate in energy consumption of around 9% per year.

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[1] Hirst, 1973

[2] Ibid.

Potential Savings

Increasing load factors offers the most productive means for reducing energy consumption in the aviation field. Increasing the tonnage load factor by 20% (e.g. from 50 to 60%) would result in a 16% savings in fuel.[1] Increasing the passenger load factor by 29.6% (e.g. 54% to 70%) yields a 22% savings in fuel.[2] Because of assorted problems associated with high passenger load factors, it is doubtful that the airlines would want to increase load factors above 70%. It is reasonable to assume a 22% reduction in energy directly consumed by certificated airlines is the maximum feasible reduction. Certificated airlines hold certificates of public convenience and necessity from the Civil Aeronautics Board, authorizing performance of scheduled air transportation over specified routes and a limited number of non-scheduled operations. It includes both domestic and international flights.

The most effective method for the increasing load factors is a reduction in capacity, but this will have consequences. Increasing load factors by 20% have been shown by Pilati to require a 17% reduction in capacity.[3] Airline personnel would have to be laid off or have to work reduced hours. A 4% reduction in total airline employment would result. Also, traveller inconvenience would increase, but estimates show that a passenger load factor goal below 70 would possess a probability of passenger rejection of less than .001.[4]

Reducing cruising speed offers savings in energy consumption. Minimizing energy cost has not in the past been achieved by minimizing overall operating cost. The latter has been the concern of the airline industry, but with rapidly rising fuel rates, one expects that reducing energy cost will be more consistent with optimization of operating cost. As part of the energy reduction related to decreasing speed, it is assumed that adjustments in altitude are simultaneously accomplished. Mutch showed a 3.5 savings from the combination of these adjustments.[1] On the other hand, Pilati calculated energy savings ranging from 1.3% to 3.0% by reducing speed with a totally different modeling approach.[2] Furthermore, a 1.3% reduction would be achieved by increasing altitude by 2,000 feet.[3] The combined reduction would range between 2.6 to 4.3% from the combination and this is very consistent with Mutch's projections.

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[1] Pilati, 1974

[2] Mutch, 1973

[3] Pilati, 1974

[4] Mutch, 1973.

Both Mutch and Pilati investigated savings involved with delays. However, their approaches were different with Mutch looking at the broader issue of inflight delays as well as ground delays. He estimates around 1.0% of the total energy consumed by certificated aircraft would be saved by improvement to air traffic control to accomplish better scheduling. Most of the energy would be saved in the domestic segment (1.7% of the domestic energy).[4] Pilati, looking only at the domestic sector, calculated a savings of .8 or 2.7% by two conservation alternatives while the aircraft is grounded.[5] The lower value is based on reducing the number of engines in operation while the higher figure assumes aircraft is towed between the terminal building and locations for take-offs and landings. Pilati's approach is implementable at least to some degree in the short range while Mutch considered that his savings would occur only over the long range. These approaches overlap in the sense that both would reduce ground consumption. A combined approach of all measures is estimated to save 1.5 to 3.0% of the total energy consumed by certificated aircraft over the long run. How close one could approach the maximum of a 3.0% savings in this category would depend on the practicality of towing. Over the short range, savings would be less than 1%.

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[1] Mutch, 1973

[2] Pilati, 1974

[3] Ibid

[4] Mutch, 1973

[5] Pilati, 1974

In summary, the following per cent savings as shown in Figure V-9 represent the maximum achievable for 1980 and 2000 associated with the three categories. They are a composite of the two major studies in this area which have laready been shown to be in agreement.

These savings were directly applied to Mutch's[1] projection for energy consumption for those years which assumed an annual growth rate of slightly over 9%. The results were plotted along with historical data and extrapolations were made to obtain savings in the years pertinent to this study. The savings range from 250 trillion BTUs in 1977 to 2208 trillion BTUs in 1990, (see Figure V-10).

2. Achievable Savings and Impacts

The achievable savings and impacts were not estimated for this measure. Only the potential energy savings are shown.

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[1] Mutch, 1973

FIGURE V-9

MAXIMUM PROJECTED PERCENT SAVINGS FROM CONSERVATION MEASURES APPLIED TO CERTIFICATED AIRLINES

	1980	2000
Reduced Load Factor	21.7	21.7
Reduce Speed-Increase Elev.	4.3	4.3
Reduced Delays	1.0	3.0
	27.0	29.0

FIGURE V-10

TOTAL PROJECTED DIRECT ENERGY SAVINGS*

FOR CERTIFICATED AIRLINES

(Trillions of BTUs)

	1970	1977	1980	1985	1990
Energy Consumption * Without Conservation	1200	1800	2453	4625	7750
Energy Consumption With Conservation	N/A	1550	1791	3339	5542
Energy Savings	N/A	250	662	1286	2208
% Savings	N/A	13.9	27.0	27.8	28.5

* Based on information in "The Potential for Energy Conservation in Commercial Air Transport" by James J. Mutch, October 1973

N/A - Not Available

D. INCREASED AUTOMOBILE EFFICIENCY

1. Maximum Energy Savings

General Discussion

Automobiles are the most widely used mode of passenger transportation and the greatest consumer of passenger transportation energy. In 1970, 87% of intercity passenger miles and 97% of urban passenger miles were travelled by automobiles.[1] In 1970, automobiles consumed 67 billion gallons[2] of fuel. This consumption is projected to increase to 108 billion gallons of fuel in 1990.[3]

Automobile efficiency is the subject of a wide ranging debate between public, governmental and industry sources. Among the many proposals for increasing automobile efficiency is the replacement of the conventional internal combustion engine with new and different engines, the use of smaller cars, especially in an urban environment, modifications of the standard Otto cycle internal combustion engine, and various engine hardware modifications. Numerous new engines have been proposed as replacements to the conventional internal combustion engine. Among these are the Diesel engine, Wankel engine, Rankine cycle engine, gas turbine, Stirling cycle engines, battery operation, fuel cell systems, and hybrid engines. Of these, only Diesel engines and Wankel engines are currently used in the production of automobiles. Each of the new engine types has its various advantages and disadvantages. All but the Diesel require significant technological development before they can be used as a fuel conserving replacement for the conventional internal combustion engine. Thus, there is considerable uncertainty as to both practicality and impact.

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[1] Hirst, 1973

[2] 1972 Statistical Abstract

[3] Chase, 1974

Recent studies have shown that the Diesel[1,2] has very limited potential for uses as a replacement. Modifications of the conventional internal combustion engine, such as stratified charge engines and advanced Otto cycle engines, pose the same problems of technological uncertainty. For this reason, it was decided to exclude engine changes and modifications from analysis. It should be noted that a study by Hittman Associates[3] prepared for the National Science Foundation does examine in detail the energy, environmental and technological considerations which arise from new engine types and modifications of the conventional internal combustion engine.

Non-engine modifications were chosen as the basis for energy savings in this study. In this sense, the list of proposed modifications is not exhaustive. Automobile weight reduction is not explicitly considered as a source of fuel savings because it is implicitly assumed in the base case forecast. This base case forecast, derived from a report to CEQ by Chase Econometric Associates,[4] assumes a decreasing proportion of larger cars.

Proposed Measures

Four methods of increasing automobile efficiency are considered in this study. These methods consist of both changes in automobile equipment on new cars and changes in owner practices which can be implemented on all cars. The following is a summary of these measures:

° Radial Tires - It is estimated, based upon a study by DOT[5] that radial tires will increase automobile mileage by 10%. By decreasing friction between the tire and the road, radial tires require the use of less motive energy. They have the additional advantages of increasing both maneuverability and safety

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[1] Hittman, 1974

[2] Eaton, 1973

[3] Hittman, 1974

[4] Chase, 1974

[5] DOT, 1973

- Aerodynamic Design - DOT[1] also estimated that aerodynamically efficient design of automobiles could decrease fuel consumption by 5%. This is one measure that could be implemented with little impact on other technical properties of automobiles.
- Continuously Variable Transmission - Ordinary automobile transmissions, whether they are manual or automatic, lose energy efficiency as they shift gears. This occurs while the cars are changing speeds. Thus, much energy is lost during that portion of travel when automobiles are not at constant speeds. A continuously variable transmission allows changes in engine speed to be continuously and automatically transferred along the drive train. This allows for the recovery of much of the energy lost in conventional manual or automatic transmissions. It is estimated that between 20% and 25% of automobile fuel use could be saved by the use of a continuously variable transmission.[2]
- Tuneups - A recent study done by the Clayton Manufacturing Company[3] for the State of New Jersey's EPA showed an average of about 5% fuel savings on tuned automobiles over their prior consumption rate. Another study by the Champion Spark Plug Company[4] found approximately the same results. It was also shown by Clayton that increasing fuel efficiency due to engine tuneups also results in decreased hydrocarbon emissions.

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[1] DOT, 1973

[2] Gres, 1973

[3] Clayton, 1971

[4] Champion, 1969

Calculations

Calculations in this report for automobile energy efficiency are based on the use of all four of the above measures in automobiles produced during and after the 1976 model year. All automobiles produced during the 1976 model year or later were assumed to have an efficiency of 20 mpg. Only engine tuneups were considered as applicable to automobiles produced prior to 1976 model year.

The methodology used was to break out the vehicle inventory in each calendar year by a number of automobiles registered in each model year . The total vehicle miles travelled by cars in each model year is computed as the product of the average vehicle miles for the model year in that calendar year times the number of model year vehicles registered. Dividing this figure by the average fuel consumption rate for the model year results in model year total fuel consumption. These fuel consumptions are then summed to yield total auto fuel consumption in a calendar year.

The production from each year was taken from statistical abstracts[1] for historical model years and was forecast based on the Chase study[2] for future model years. The number of automobiles from each model year left in the calendar year was calculated based upon scrappage curves developed by Chase. The scrappage rates determined by Chase assume an estimated 10 to 11 years average vehicle lifetime. A slight trend towards cars being scrapped earlier is projected to continue. Baseline miles per gallon for each model year were also taken from the Chase study. These results, as stated earlier, show a continuing trend towards better fuel economy as the proportion of smaller cars is projected to increase.

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[1] Statistical Abstract, 1972

[2] Chase, 1974

The amount of fuel consumption for automobiles varies with the age of the auto. Both the number of miles driven and the fuel efficiency of autos change as they become older. The Federal Highway Administration determined in the National Personal Transportation Study[1] the relative levels of vehicle miles travelled by automobiles of different ages. These relative levels are projected to continue in the future. Base case calculations of energy consumption are shown in Appendix E.

Results

Figure V-11 summarizes the savings potential resulting from the implementation of the four energy saving methods. This figure shows that most of the savings will occur due to the implementation of all four measures on post-1975 cars and that those savings that occur due to tuneups on pre-1976 cars diminish as these cars are scrapped. These are nonetheless significant savings through about 1985.

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[1] FHWA, 1972.

FIGURE V-11

MAXIMUM ENERGY SAVINGS FROM INCREASED AUTO EFFICIENCY
(10^{12} BTU)

YEAR	PRIOR TO 1976 MODELS (tune ups)	1976 AND LATER MODELS (4 measures)	TOTAL SAVINGS
1977	365	810	1175
1980	205	1690	1895
1985	40	2790	2830
1990	0	3460	3460

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

To increase energy efficiency of automobiles the following implementation strategies were assumed:

- mandated use of radial tires
- mandated energy efficient aerodynamic design
- voluntary tune-ups
- mandated variable transmissions

At the present time, a large proportion of car owners have equipped their cars with radial tires. In addition, many new cars come equipped with radial tires as standard equipment. Even without a mandate, there is a high probability that most cars by 1980 will have radial tires. It has been assumed for this analysis that with or without a mandate, 100% implementation can be achieved by 1980.

Both variable transmissions and aerodynamic design for passenger vehicles, if mandated, would require several years for implementation into the production lines. Because basic research has been accomplished, implementation can be achieved as a function of development time required from date of mandate. For the purposes of this analysis it has been assumed that a mandate (under EPA) would be issued in 1975. Allowing five years (judgmental assumption) for actual implementation, all post-1979 vehicles would be equipped with variable transmissions and would meet a specified aerodynamic design standard.

Voluntary tune-ups will be primarily a function of economics and public appeal. While the frequency of tune-ups would probably increase over the near term as a result of public appeal, it is uncertain as to how much of a permanent effect could be achieved. Over the long term, frequency of tune-ups would probably decline back to the present level.

This judgmental assumption is based on the probable direct out-of-pocket added cost for additional tune-ups. If it is assumed that the average automobile travels 6,000 miles in six months; at 5%, added efficiency fuel costs would be reduced by $13.75. Assuming tune-up cost between $35 and $50, the added consumer cost would be approximately $21 to $36.[1] For purposes of the analysis, it has been assumed that the level and frequency of tune-ups on 1975 and earlier models will not significantly increase over present frequency. It has also been assumed that all 1976 and later models would be tuned at the frequency assumed in the conservation measure.

Feasible energy savings which could result from the implementation strategies are estimated as follows:

Year	Maximum Savings (BTU's x 10^{12})	Estimated Attainable Savings (BTU's x 10^{12})
1977	1175	0
1980	1895	1690
1985	2830	2790
1990	3460	3460

The above schedule assumes that each measure will be fully implemented by 1980 and that for post-1980 automobiles a high proportion of tune-up maintenance will be performed. The reduction of energy savings from the maximum potential does not reflect new net savings from increased tune-ups of pre-1976 automobiles, but does reflect 100% savings from increased tune-ups on post-1975 models. These assumptions were necessary since data on actual or probable compliance were not available.

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[1] Tune-up costs are assumed values only. More detailed studies (e.g., (Clayton, 1971) have shown cost reduction as a result of annual tune-ups.

IMPACTS

Private Consumer

The private consumer will (1) realize a cost savings from increased fuel efficiency and (2) incur an added capital cost for improved automobiles. Fuel savings are estimated as follows:

Year	BTU Savings x 10^{12}	Estimated[1] Gallons Saved x 10^{12}	Cost Savings At $0.55/Gallon (Millions)
1977	0	0	0
1980	1969	145	$7963
1985	2790	205	11283
1990	3460	254	13993

Insufficient data were available to estimate the added costs associated with design changes and transmission change. It is assumed that no significant new tune-up costs will be incurred since the frequency of tune-ups was not expected to increase significantly.

Added costs for radial tires will be incurred. However, since a large proportion of new automobiles are now equipped with radial tires, it has been assumed that the added cost for equipping all new cars will be incurred with or without mandate. Within this analysis, an added dollar cost for mandated radial tires has not been estimated and assigned to consumer impacts.

Public Sector

Federal and state governments stand to lose gasoline tax revenue at an average rate of $0.11 per gallon. The estimated tax revenue loss between 1977 and 1990 would be $25,146 million. The reduction in gasoline consumption could result in the avoidance of an estimated $9,948 million in oil imports between 1977 and 1990.

Scarce Materials and Resources

No significant materials/resources impacts are anticipated from implementation of these measures, since each is well within the scope of present technological capabilities.

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[1] Assumes 136,000 BTU's per gallon.

Quality of Life

Increasing the efficiency of automobiles should have minimal impact on life styles.

Environment

Air pollution emissions have decreased significantly due to Federal emission standards, and are expected to continue to decrease following the directives set out in the Clean Air Act Amendments of 1970. It is assumed that programs to increase automotive efficiency will allow autos to continue to meet these standards. Based on currently available technology, however, it is unlikely that increased auto efficiency will result in decreased vehicle emission reduction. Reduced demand for gasoline will result in decreased emission from petroleum exploration, extraction, refining, and marketing. No aggregate emission effects were estimated for this concentration measure.

Private Industry

Except for energy related industries (e.g., refining, distributing, and retail), improving automobile efficiency is likely to have little net effect on private industry. However, it would have some favorable and unfavorable effects within selected industrial categories.

For example, a specific industry impact would be the change-over from present transmission production to variable transmission production. For each strategy (radial tires, design change and transmissions) it has been assumed that no net impact will be incurred. This means that any added costs would be passed on to the consumer and that demand levels would not materially change.

Capital costs associated with production changeover for design, transmissions and radial tires are assumed to be the same as those normally incurred on annual model design changes and technical improvements.

Employment

No employment impact was estimated due to a lack of data and the fact that the employment changes were likely to be offsetting and no large net effect was deemed likely.

A summary of effects is shown in Figure V-12.

Figure V-12

AUTO EFFICIENCY IMPACT STUDY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	1175	1895	2830	3464	33,688
2. Estimated Feasible	0	1690	2790	3464	31,089
B. Impacts (Millions of Dollars)					
1. Private Industry		Insufficient Data			
2. Private Consumer Savings	0	$7963 m.	$11283 m.	$13993 m.	$125,728 m.
3. Public Sector					
Government Tax Loss	0	($1592 m.)	($2257 m.)	($2799 m.)	($25146 m.)
Balance of Payments	0	$ 541 m.	$ 893 m.	$1107 m.	$ 9948 m.
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)		Not estimated (see text).			

E. INCREASED USE OF PIGGYBACK AND CONTAINERIZATION

1. Maximum Energy Savings

General Discussion

Intercity freight represents a significant portion of U.S. transportation. In 1970, it accounted for 2.4 Quads[1] of energy.[2] Sixty percent of intercity freight in ton miles of traffic consuming 70.6% of this energy is accounted for by rail and truck movements.[3] Although truck ton miles were only slightly over half those of rail, trucks consumed more than twice the energy of rail transport. Figure V-13 summarizes these relationships.

Railroads are generally a more efficient mode of freight transportation than trucks. This relative advantage of rail is due physically to a smaller amount of rolling friction between the steel train wheels on a steel rail when compared to a rubber wheel on a hard surface. Larger freight payloads for each unit of motive energy are thus allowed. Counterbalancing, but not eliminating this advantage, is the practice of rail freight cars often being transportated not loaded or partially loaded while the proportion of truck trailers which travel in this manner is much smaller.

An additional advantage of rail shipment is the greater carrying capacity in terms of ton miles of a railroad line compared to an intercity highway. Increased rail traffic can be accommodated with less congestion than increased truck traffic.

Since 1960, the overall energy efficiency of intercity freight traffic has declined due to a modal shift from rail freight delivery to truck freight delivery. The factors which caused this shift are the increased speed, better service, and indirect

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[1] Quad equals 1 quadrillion or 10^{15} BTU

[2] Hirst, 1973

[3] Ibid

FIGURE V-13

ENERGY CONSUMPTION OF INTERCITY RAIL AND TRUCK TRAFFIC

(1970)

	TRAFFIC (10^9 ton miles)	ENERGY INTENSIVENESS (BTU/ton mile)	ENERGY USE (10^{12} BTU)
RAIL	773.5	670	518
TRUCK	419.9	2800	1175

Source: Hirst, 1973

government subsidies provided to trucking. This reversed the trend of the 1950's in which total freight energy actually decreased as railroads converted to Diesel locomotives.

A measure with which to increase freight transport efficiency in the future would be to reverse current modal trends and shift back from truck to rail transport. Rail and truck compete primarily for traffic in manufactured goods. Shipments of bulk commodities travel more by rail, while shipments of higher unit value manufactured goods tend to be shipped by truck. The average trip length of intercity truck shipments is 300 miles, while intercity rail shipments average 500 miles.[1] The average speed (from pick-up to delivery including waiting time in rail yards) for rail freight is 20 mph, while that for a truck is around 40 mph.[2] These facts highlight some of the problems faced in stimulating a reversal of the current modal shift trends. A rail freight delivery system would have to be faster than the current system, provide better service, especially for small, less than carload shipments, provide increased security, and allow for ease of intermodal transfer to places not directly on the rail line, all at a competitive cost.

The use of containerization and piggyback has been proposed as one means of effecting such a mode shift because it does meet these criteria. Containerization refers to the use of containers which can be shifted from vehicle to vehicle as the shipment of the freight inside progresses. It is often referred to as "container on a flat car" (COFC). Piggyback usually refers to the shipment of truck trailers by rail and is often termed "trailer on flat car" (TOFC). Also, in common use is the term "intermodal traffic" referring to both of these modes.

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[1] Hirst, 1973

[2] Ibid

In 1973, 1.54 million TOFC/COFC carloadings represented 5.6% of all rail carloadings.[1] This was a 29% increase since 1971. Of this 5.6% only about 6% to 10% was COFC.[2] The greatest proportion of the increase in intermodal traffic also occurred in TOFC.

Factors Influencing Efficiency

For domestic intercity transportation, TOFC has several advantages over COFC. Containerization requires much larger investments in both the containers and transfer facilities. The facilities are especially expensive; for a particular installation investments are necessary for both marshalling yards and large cranes to carry the containers. Additionally, containerization is slower due to the amount of time necessary to move containers from one mode to another. There are also institutional problems with ownership and allocation of containers as well as shipments of different sized containers.

COFC is now primarily used for international shipping and its extension into land transport modes. Indeed, one cause of the expansion of COFC in the U.S. has been the establishment of a "land bridge" for shipments from Japan to Europe and vice versa. This eliminates the necessity for these shipments to pass through the Panama Canal, thus saving valuable time for the international shipper.

By contrast, TOFC is used primarily for domestic shipments of freight. While rail loading facilities are required, they need not be as elaborate as with COFC. In addition to a lessened capital investment which still will be considerable, TOFC allows flexibility in both ownership of trailers and possible routes of travel. For these reasons, TOFC can be expected to be the dominant type of intermodal traffic in the U.S. and can be expected to continue its rapid growth even without government intervention.

Currently, about 90% of the 40,000 TOFC flat cars are owned by Trailer Train, Inc., a Chicago based company, which is jointly owned by the railroads.[1] A number of different plans are available for shippers who wish to use TOFC. These plans allow for different competitive patterns of rates, ownership, and delivery of intermodal freight. Railroads have, in general, given better marketing emphasis to intermodal freight than conventional freight because of its more competitive position relative to trucking. This has, in a large part, been responsible for the recent spectacular growth in intermodal traffic.

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[1] Railway Age, June 24, 1974

[2] Estimate of Sheldon Landy, Director of Planning, Trailer Train Company

The energy efficiency of COFC and TOFC relative to conventional rail freight has not yet been the subject of any published studies. Robert Reebie Associates of Greenwich, Connecticut is currently conducting a comprehensive study of intermodal freight traffic which will eventually address itself to this question. Some preliminary results are now available,[2] but it is now only possible to identify the factors that influence intermodal energy efficiency and roughly estimate the relative efficiency on that basis. It should be noted that, in addition to Robert Reebie Associates, DOT's Transporation System Center in Cambridge, Massachusetts also plans a study in the area of intermodal energy efficiency. This study has not yet started.

There are several factors which are important when comparing intermodal energy efficiency to that of conventional rail:

a. Amount of back-hauling - Currently, intermodal shipments have a smaller number of empty cars being back-hauled, which increases their energy efficiency. This is due primarily to the better management of intermodal freight which uses selectivity in customer and route choices. To some extent, this is a function of the relative smallness of the current intermodal traffic. Such selectivity can be expected to diminish as intermodal shipments increase in volume, thus eliminating the backhauling advantage.

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[1] Wall Street Journal, 1974

[2] DeBoer, D. J., 1974

b. Intermodal transfer energy - This is the amount of energy needed to transfer containers or trailers between trucks and trains. Although no estimates are currently available, it is probably considerably smaller in magnitude than rail travelling energy. It should be much larger for COFC than TOFC because of the cranes necessary to transfer containers.

c. Speed - Intermodal trains travel faster than conventional trains so as to be able to compete effectively with truck traffic. This, of course, uses more energy. It has been proposed that intermodal trains would probably travel 40 - 60 mph.[1]

d. Wind resistance - COFC trains experience less wind resistance than conventional trains because of the low profile of the containers. TOFC trains experience greater wind resistance than conventional trains because of the less streamlined profile of the truck trailers or flat cars. At the higher speeds of TOFC travel, these effects could be quite pronounced.

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[1] Sheldon Landy, Director Development Planning, Trailer Train Company, personal communication

e. Amount of freight payload per train - The weight of the freight payload carried by a TOFC/COFC train may be considerably smaller than a conventional train. Not only does the TOFC freight tend to be lighter per unit volume, but the volume available for shipment is decreased. Intermodal freight tends to be manufactured goods rather than bulk goods and the trailers or containers take up space and weight denied to the payload.

f. Amount of drayage at origin or destination - Since TOFC facilities may not be located at either the shipping or final destination point, additional local truck hauling is often necessary. This local movement, or "drayage", is more energy intensive than the rail part of the movement of TOFC freight. Elimination of drayage is not practical or possible because it is the ability to utilize such services that would make TOFC attractive to potential users.

Calculation of Energy Savings

We shall assume that the entire amount of freight transferred from trucks is to TOFC rather than COFC. On the basis of the above factors, it is estimated that TOFC would have an energy intensiveness of about 1000 BTU/ton-mile.[1]

For the base case estimate of freight shipment by truck and train, it is estimated that conventional train ton miles will increase at 2.0%, truck at 3.3%, and TOFC/COFC ton-,iles at 9.0%.

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[1] Peat, Marwick, 1974 use 700 BTU/ton-mile but this figure is assumed to be somewhat low

These are consistent with past historical trends.[1,2] Energy intensiveness is estimated at 2800 BTU/ton miles for trucking[3], and 655 BTU/ton miles for conventional rail. Hirst[4] estimated total rail energy efficiency at 670 BTU/ton miles in 1970. Allowing for that year's percentage of intermodal shipments at 1000 BTU/ton mile, yields 665 BTU/ton miles for conventional rail freight. These energy intensities are projected to continue into the future. Figure V-14 shows the base case forecasts for truck and rail ton miles and energy.

Intermodal shipments have increased not only as a result of their increasingly competitive positions, but also because of fuel shortages. Many shippers have turned to TOFC as a way of avoiding slowdowns in truck deliveries induced by the recent fuel shortages. Even trucking companies are already using intermodal traffic as a means of avoiding fuel shortages and increased prices.[5,6]

The potential for increased use of TOFC comes from two sources; shipments that would have originally gone by rail and those which would have originally gone by truck. To the extent that traffic is diverted from conventional rail freight, the overall energy efficiency is decreased. Preventing this shift, however, may only decrease energy efficiency still further because the use of TOFC should prevent the use of even more inefficient trucking. Indeed, TOFC is looked upon by the railroad industry primarily as a means of checking the historical trend

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[1] Railway Age, 1974

[2] Hirst, 1973

[3] Ibid

[4] Ibid

[5] Wall Street Journal, 1974

[6] Barrons, 1974

FIGURE V-14

BASE CASE FORECAST OF TRUCK AND RAIL FREIGHT AND ENERGY CONSUMPTION

MODE	CONVENTIONAL RAIL		TOFC/COFC		ALL RAIL		TRUCKING		TOTAL TRUCK & RAIL	
YEAR	FREIGHT (10^9TM)	ENERGY (10^{12}BTU)	FREIGHT (10^9TM)	ENERGY (10^{12}BTU)	FREIGHT (10^9TM)	ENERGY (10^{12}BTU)	FREIGHT (10^9TM)	ENERGY (10^{12}BTU)	FREIGHT (10^9TM)	ENERGY (10^{12}BTU)
1970	738[2]	483[2]	36[2]	36[4]	774[1]	519[1]	420[1]	1175[5]	1194[1]	1694[1]
1977	842	552[3]	68	68[4]	910	620	519	1453[5]	1429	2073
1980	894	585[3]	89	89[4]	983	674	573	1604[5]	1556	2278
1985	988	647[3]	140	140[4]	1128	787	676	1893[5]	1804	2680
1990	1092	715[3]	219	219[4]	1131	934	797	2232[5]	2108	3166

Assumed Growth Rates in Freight:

Conventional Rail	2.0%
TOFC/COFC	9.0%
Trucking	3.3%

1. Sources: Hirst, Eric, Energy Intensiveness of Passenger and Freight Transportation, 1950-1970, ORNL-NSF-EP-44, April 1973.

2. Source: Welty, Gus, "For TOFC/COFC a Brighter than Bright Future--if...;" Ralway Age, June 24, 1974.

3. Energy Intensity of Conventional Rail - 655 BTU/Ton Mile.

4. Energy Intensity of TOFC/COFC - 1000 BTU/Ton Mile.

5. Energy Intensity of Intercity Trucking - 2800 BTU/Ton Mile.

towards trucking.[1,2,3] On the other hand, shifting freight from trucking to TOFC should increase energy efficiency by about 1800 BTU/ton mile based upon MATHERMATICA's rough estimate of TOFC energy efficiency.

The Robert Reebie study is currently attempting to calculate the total amount of freight carried by truck and rail which is amenable to intermodal shipment. In 1971, they estimated that only 4% of the freight shipped that was amenable was actually shipped by TOFC/COFC.[4] They further determined that the greatest amount of this traffic would be in the 400 to 1200 mile distance of shipment category.

Applying the above estimate of intermodal potential, it is estimated that 48.9% of rail and truck traffic can be carried by TOFC. This relationship is assumed to continue through 1990. Of the increase in potential for intermodal traffic, 33.7% is estimated to be from truck traffic and 66.3% from conventional rail. Figure V-15 shows the results of this potential mode shift if realized. Total ton miles are assumed to remain the same as in the base case. Figure V-16 shows the components of the energy shifts involved. Up to a 397 trillion BTU energy savings in 1990 is projected.

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[1] DeBoer, 1974

[2] Railway Age, 1974

[3] Landy, 1974

[4] DeBoer, 1974

FIGURE V-15

CONSERVATION CASE FORECAST OF TRUCK AND RAIL FREIGHT AND ENERGY CONSUMPTION

MODE	CONVENTIONAL RAIL		TOFC/COFC		ALL RAIL		TRUCKING		TOTAL TRUCK & RAIL	
YEAR	FREIGHT (10^{9}TM)	ENERGY (10^{12}BTU)	FREIGHT (10^{9}TM)	ENERGY (10^{12}BTU)	FREIGHT (10^{9}TM)	ENERGY (10^{12}BTU)	FREIGHT (10^{9}TM)	ENERGY (10^{12}BTU)	FREIGHT (10^{9}TM)	ENERGY (10^{12}BTU)
1970	738[2]	483[3]	36[2]	36[4]	774[1]	519[1]	420[1]	1175[5]	1194[1]	1694[1]
1977	424	278	699	699	1123	977	306	857	1429	1834
1980	449	294	761	761	1210	1055	346	969	1556	2024
1985	496	325	883	883	1379	1208	425	1190	1804	2398
1990	549	360	1031	1031	1580	1391	528	1478	2108	2869

1. Sources: Hirst, Eric, Energy Intensiveness of Passenger and Freight Transportation, 1950-1970, ORNL-NSF-EP-44, April 1973.
2. Source: Welty, Gus, "For TOFC/COFC a Brighter than Bright Future--if...;" Ralway Age, June 24, 1974.
3. Energy Intensity of Conventional Rail - 655 BTU/Ton Mile.
4. Energy Intensity of TOFC/COFC - 1000 BTU/Ton Mile.
5. Energy Intensity of Intercity Trucking - 2800 BTU/Ton Mile.

FIGURE V-16

COMPONENTS OF ENERGY SAVINGS

YEAR	CHANGE IN MODE TRAFFIC (10^9 Ton Miles)	SAVINGS IN MODE ENERGY (10^{12} BTU)	SAVINGS IN TOFC ENERGY DUE TO MODE (10^{12} BTU)	NET CONTRIBUTION TO ENERGY SAVING (10^{12} BTU)
Changes in Traffic and Energy Due to Shift from Convention Rail				
1977	-418	274	-418	-144
1980	-445	291	-445	-154
1985	-492	322	-492	-170
1990	-543	356	-543	-187
Changes in Traffic and Energy due to Shift from Trucking				
1977	-213	596	-213	383
1980	-227	636	-227	409
1985	-251	703	-251	452
1990	-269	753	-269	484

- Maximum Savings due to TOFC/COFC

	Net Contribution to Energy Savings (10^{12} BTU)		Maximum Total Energy Savings
YEAR	TRUCKING	CONVENTION RAIL	TRUCKING AND RAIL
1977	383	-144	239
1980	409	-154	255
1985	452	-170	282
1990	484	-187	297

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

This measure focuses on encouraging highway users to utilize the more fuel-efficient alternatives of container or trailer on flatcar (COFC or TOFC) by regulatory avenues, such as legislated economic incentives and by voluntary public cooperation.

Feasible potential energy savings through increased use of COFC/TOFC will be seriously limited by (1) equipment constraints, (2) service levels lower than truck, and (3) terminal congestion problems. Most of these problems stem from the rail industry and equipment manufacturers being stretched to the limit to meet and maintain their present high rate of annual growth.

On the assumption that economic incentives could induce an increase in demand for TOFC/COFC services over and above the present growth rate, it is unlikely that the rail industry could accommodate more than a small proportion of incremental increase for the reasons just stated. For the purposes of the analysis, it has been assumed that new demand would be in excess of the amount the rail industry could realistically handle.

Based upon these constraints, industry consultants[1] estimate judgmentally that the incremental increase in freight diversion to COFC/TOFC that could be accommodated by the rail industry would be as follows:

	(1)	(2)	(3)	(4)	(5)
Year	Maximum COFC/TOFC Diversion From Truck & Conventional Rail (Ton-miles x 10^9)	Maximum Energy Savings (BTU's x 10^{12})	Feasible Percent Diversion	Estimated Diversion From Truck And Rail (Ton-miles x 10^9; Col.3 x Col.1)	**Feasible BTU's Saved (BTU x 10^{12}) Col.3 x Col.2**
1977	631	239	1%	6.3	2.4
1980	672	255	2%	13.4	5.1
1985	743	282	4%	29.7	11.3
1990	812	297	6%	48.7	17.8

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[1] PMM&Co., rail transportation consulting practice.

IMPACTS

Private Consumer

No significant economic benefit or cost is expected to accrue to the private consumer.

Public Sector

Railroads may not be able to generate the cash or acquire the capital needed to finance the feasible growth in the years ahead. Private industry, or even the motor carriers themselves, may offer some or all of the capital required. The balance could require government-guaranteed loans which would, in all likelihood, be repaid. No net cost to the government is therefore anticipated. Avoided oil imports are estimated at $43 million between 1977 and 1990.

Scarce Materials and Resources

Availability of materials and production constraints present the major impedences to the rail car manufacturing industry.

Quality of Life

There should be no significant quality of life impacts associated with implementation of this measure, since it entails a change in a process (freight handling) as opposed to a curtailment of a lifestyle activity.

Environment

CO pollutants can be reduced by 3.2 million pounds (.002% of all CO emissions) in 1977. In 1980, this figure increases to 8.3 million pounds (.006%). For 1985 and 1990, CO reductions possible are 18.3 million pounds (.025%); and 96 million pounds (.152%), respectively.

Similarly, HC emissions can be reduced by the following amounts:

YEAR	PERCENT
1977	.002% of all HC emissions
1980	.006%
1985	.017%
1990	.028%

Air pollution reduction impacts from this measure are minimal, especially as the bulk of the emission reductions would occur outside of metropolitan areas. Truck noise and truck-enhanced traffic congestion can be reduced through this measure, since it entails fewer trucks on the road at any given time.

Private Industry

Shippers will probably receive only minimal net economic benefits, since there is no justification for a reduction in rates if similar or superior service levels can be provided. Railroads, on the other hand, will benefit from increased revenues.

Rail revenue increases would result from (1) freight diverted from trucks; and (2) operating cost savings from freight diverted from conventional rail service. Assuming \$.0254[1] per ton-mile revenue, added revenue from diverted truck freight would be as follows:

YEAR	TRUCK FREIGHT DIVERSION (TON MILES x 10^9)	ESTIMATED NEW REVENUE (MILLIONS \$)
1977	2.13	\$ 54
1980	4.59	117
1985	10.04	255
1990	16.14	410

Added fuel costs from conventional rail freight diversion are estimated as follows;

YEAR	CONVENTIONAL RAIL FREIGHT DIVERSION (TON MILES x 10^9)	ESTIMATED ADDED FUEL COSTS (GALLONS x 10^6)	COST (MILLIONS \$)
1977	4.17	2.7	\$ 1.1
1980	8.86	57.2	22.9
1985	19.66	126.8	50.7
1990	32.56	210.1	84.0

In determining motor carrier savings, an average load of 14 tons (higher than the all-truck average of 11 tons) and including allowance for empty returns and approximately \$.50 long-term variable cost per trailer mile were assumed. Motor carrier savings are thus equal to the difference between cost savings and expenses (revenues paid to railroads). These savings are as follows:

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[1] Rail yearbook of Railroad Facts, Association of American Railroads, 1974.

YEAR	TON MILES x 10^9 DIVERTED	MOTOR CARRIER SAVINGS 3.57¢ PER TON MILE ($ x 10^6)	RAILROAD REVENUE @2.50¢/TON MI. ($ x 10^6)	NET TRUCK SAVINGS ($ x 10^6)
1977	2.13	$ 76	$ 54.1	$ 21.9
1980	4.54	162	115.3	46.7
1985	10.04	358	255.0	103.0
1990	16.14	560	410.0	150.0

Employment

About 50 percent of railroad revenues are spent for labor. Assuming an average wage of about $13,600 per railroad employee, new employment is calculated as follows:

YEAR	NEW RAIL EMPLOYMENT DUE TO TRUCK DIVERSION TO COFC/TOFC (Rev. x .50 ÷ 13,600)	TRUCK EMPLOYMENT LOST DUE TO COFC/TOFC DIVERSION (COST SAVINGS x .50 ÷ 13,000)
1977	2,000 jobs	840 jobs
1980	4,200	1,800
1985	8,300	4,000
1990	15,000	5,800

Assuming fuels are purchased directly from the major oil company, major oil employment decreases would be almost insignificant.

A summary of impacts is shown in Figure V-17.

FIGURE 17
COFC/TOFC IMPACT SUMMARY

	Annual Impact 1977	1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	239	255	282	297	3799
2. Estimated Feasible	2.4	5.1	11.3	17.8	135
B. Impacts (Millions of Dollars)					
1. Private Industry					
Rail Industry Added Revenue	$ 54m	$117m	$255m	$410m	$3109m
Rail Industry Added Cost	($ 11m.)	($ 23 m.)	($ 51 m.)	($ 84 m.)	($ 599 m.)
Motor Carrier Cost Saving	$ 22m.	47 m.	$103 m.	$150 m.	$1196 m.
2. Private Consumer		None Estimated			
3. Public Sector					
Government		None Estimated			
Balance of Payments	$0.8 m.	$1.6 m.	$3.6 m.	$5.7 m.	$43 m.
4. Employment (Jobs)					
Rail Industry	2000	4200	8300	15100	15100
Motor Carriers	(840)	(1800)	(4000)	(5800)	(5800)
5. Environment (Percent Reduction)					
CO Reduction	.0022%	.006%	.025%	.15%	
CH Reduction	.0024%	.006%	.017%	.028%	

F. INCREASED USE OF PUBLIC BUS TRANSIT

General Discussion

The preponderant volume of urban transportation is now carried by automobiles. Urban public transit currently represents a small and declining percentage of urban transportation. In 1970, only three percent of total urban passenger miles and one percent of urban passenger energy was accounted for by public transportation.[1] This has resulted not only in increased urban congestion, but also less efficient use of energy because autos are more energy intensive then public transportation.

A major problem in estimating by synthesis of other studies the maximum potential for energy conservation by mode shift is that almost all of them assume hypothetical mode shifts. No judgment is actually given as to what the practical potential is. For instance, Husted[2] proposes shifting 50% of city comuters to mass transit. If this is done, he projects that 2.7% of total transportation energy could be saved. It is not stated why 50% was chosen as a comparison. Hirst[3] does the same thing, but assuming only a 10% increase in mass transit usage. Millaris and Strombotne[4] made a similar analysis.

Analytical Premises

Rather than use totally hypothetical mode shifts, MATHEMATICA has attempted to estimate bounds of feasible public transit carrying capacity. These estimates are based on rough assumptions of the demand for transit services and productive capacity. By no means can they be interpreted as definitive answers to the question of what the actual potential is. Instead, it is believed that they should give a rough estimate only of the order of magnitude of such potential savings and the technical issues involved.

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[1] Hirst, 1973

[2] Husted, 1973

[3] Hirst, 1973

[4] Millaris and Strombotne, 1973

The volume of bus traffic is more than twice as large as various rail commuter modes, 1.6 billion passengers were carried on commuter rail lines while 3.7 billion were carried on urban buses.[1] Because of the large investment in facilities necessary for rail commuter expansion, it is assumed that significant expansion of commuter rail traffic would be both more expensive and more controversial than a corresponding expansion in bus traffic. Furthermore, it is believed that bus traffic provides greater versatility and potential as to type of area served, route, and scheduling. For these reasons it was decided to limit the analysis to the potential for local bus transit.

Bus Potential

As the population of the United States has become more affluent over the last 30 years, people have acquired autos and began using them in place of the public transportation on which they formerly relied. Between 1945 and 1973 total paid transit passengers declined from 19.0 billion to 5.3 billion.[2] Total bus transit paid passengers declined from 8.3 billion to 3.7 billion.

Local bus companies responded in several ways to the declining number of passengers. First, they raised fares to compensate for lost revenue. Still greater deficits resulted. Second, they changed the way they used their inventories of buses.

Figure V- 18 represents a historical summary of local transit bus use. From this figure it can be seen that the total number of buses has remained approximately the same since 1945,

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[1] ATA, 1973

[2] Ibid

FIGURE V-18

HISTORICAL VEHICLE MILES PER BUS[1]

YEAR	VEHICLE MILES (10^6)	NUMBER OF BUSES	VEHICLE MILES PER BUS
1940	1194	35,000	34,125
1945	1722	49,670	34,600
1950	1895	56,870	33,350
1955	1710	52,400	32,630
1960	1576	49,600	31,800
1965	1528	49,600	30,810
1970	1409	49,700	28,350
1973	1370	48,300	21,330

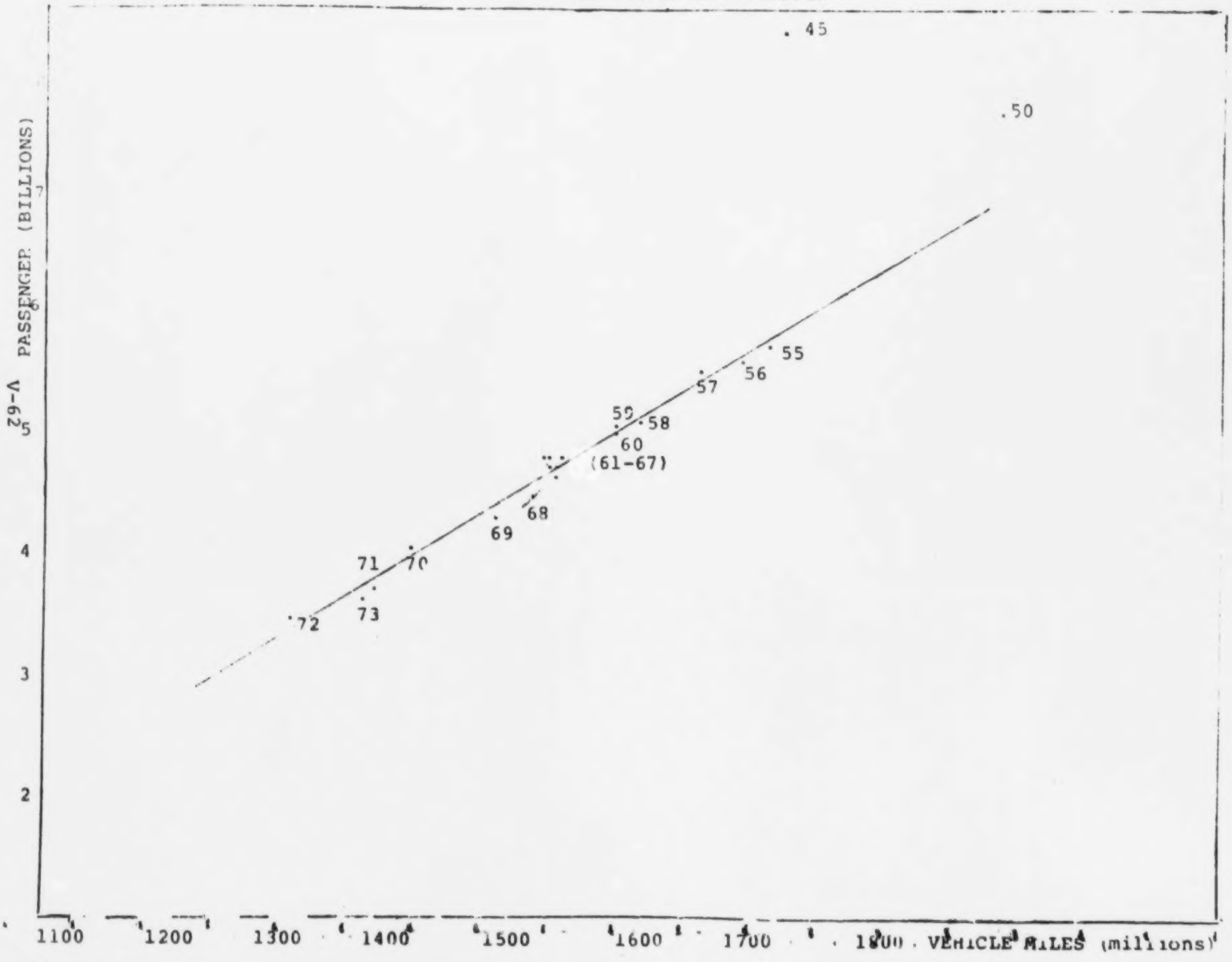
1. ATA, 1973 - 1974 Transit Facts.

that is about 50,000.[1] It can also be seen that the average number of vehicle miles driven each year by buses has decreased from 34,600 in 1945 to 21,330 in 1973.[2] Assuming an average speed of 20 mph, the 1973 figure works out to 20.5 hours of operation per week for each bus.

Figure V-19 plots number of passengers against total vehicle miles driven by buses. An almost perfectly linear plot results for years from 1960 to 1973. Points prior to 1955 lie well above the line. The further one goes back, the more VMT and passengers, the higher the increase. An interpretation of these results is that between 1945 and 1955 the demand for bus transportation declined as the public shifted to auto transportation. Between 1955 and 1973, with auto transportation saturated, a constant passenger demand to vehicle mile relationship arose. For any given total number of passengers, a corresponding predictable vehicle mile level of service is required. The inverse slope of this line (vehicle/passenger mile) can be thought of as the "passenger" elasticity of demand for bus vehicle mile.

The curve shown does not imply a future causal relationship between vehicle miles of bus service provided and numbers of bus passengers. Although a relationship exists, it is not necessarily as simple as a linear fit between two variables. What the curve does show, however, are the levels of bus vehicle mile service that in the past have corresponded to levels of passenger use. It is merely projected that for increasing passenger use, bus service of near the levels shown would be required.

BUS PASSENGER VS. VEHICLE MILES



The first way that the number of passengers can be increased is to increase the number of vehicle miles operated per bus. By how much? The estimate that buses are already operated 20.5 hours per week leaves 147.5 hours left per week for operation, but then there is no time for maintenance and there is wasteful oversupply of buses at times of very low potential demand, such as the early hours of weekday mornings. Moreover, some bus capacity may be used by transit companies primarily only to cover peak rush hour demand. The year in which buses were operated at the most vehicle miles is 1945, during which buses averaged 34,600 vehicle miles. This was at a time when bus companies were experiencing their greatest demand for services and were motivated to run their fleets efficiently. For this reason, the value of 35,000 vehicle miles per year has been assumed to be the maximum vehicle mile per bus in practical operation. This would have represented a 23.5% increase in vehicle miles over the 1970 usage and could have produced a 43% increase in passenger capacity.

In addition to operating the stock of buses a greater amount, additional vehicle miles can be produced by producing more buses. Over the past 15 years, both bus production and bus scrappage have approximately averaged 2500 buses per year.[1] This has produced a fairly constant fleet size of about 50,000 buses. The average lifetime of buses, according to American Transit Association spokesmen,[2] is now over 15 years. This has produced what is now a rather old fleet. MATHEMATICA estimates that in the future vehicle scrappage will average about 3500 per year. Also, according to American Transit Association spokesmen, maximum bus production capacity is about 7,000 buses per year. This assumes full utilization of available resources including 3 shifts per day at plants.

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[1] ATA, 1974

[2] Ibid

Assuming about 7,000 buses are produced and 3500 scrapped each year until 1990, the following schedule is feasible:

Year	Number
1976	47,500
1977	51,500
1980	65,000
1985	82,500
1990	100,000

Figure V-20 shows base case and conservation case forecasts of bus transporation. The base case forecast assumes a continuation of current trends while the after measure forecast assumes the projected maximum feasible production and vehicle miles. The projected number of passengers is slightly under the historical trend line of passengers versus vehicle miles because of an assumption that not all potential customers are returnable. Based on ATA data, it is estimated that an average passenger trip is 6.54 miles by bus.

Energy savings occur as passengers are shifted from auto transportation to bus transportation. The reduction in auto vehicle miles resulting from a shift of the entire amount of increase bus passenger miles from autos is calculated in Figure V-21. This results in an increase in bus fuel consumption and a decrease in auto fuel consumption. Since auto travel is more energy intensive than bus transportation, the total energy effect is a net saving. This saving is also shown in Figure V-21. Total energy savings are projected to be 121.3 248.8, 414.2 and 574.7 trillion BTU in 1977, 1980, 1985 and 1990 respectively.

FIGURE V-20

BASE CASE PROJECTIONS OF INTRA-CITY BUS UTILIZATION

YEAR	PASSENGERS (10^9)	PASSENGER MILES (10^9)	VEHICLE MILES (10^9)	ENERGY (10^{12} BTU)
1970	4.06[1]	26.5[2]	1.41[1]	44.9[1]
1977	3.60[3]	23.5[2]	1.32[3]	42.0[3]
1980	3.48[3]	22.8[2]	1.30[3]	41.4[3]
1985	3.30[3]	21.6[2]	1.27[3]	40.4[3]
1990	3.20[3]	20.9	1.25[3]	39.8[3]

CONSERVATION CASE PROJECTION OF INTRA-CITY BUS UTILIZATION

YEAR	PASSENGERS (10^9)	PASSENGER MILES (10^9)	VEHICLE MILES (10^9)	ENERGY (10^{12} BTU
1977	6.12	40.0	1.80	57.2
1980	8.76	57.3	2.28	72.6
1985	12.12	79.1	2.89	92.0
1990	15.47	100.7	3.50	111.4

1. ATA, 1973 - 1974 Transit Facts.
2. Estimated for an average trip of 6.54 miles, based on ATA data.
3. Projected current trends.

FIGURE V-21

PASSENGER SHIFTS AND ENERGY SAVINGS DUE TO INCREASED LOCAL BUS USE

YEAR	LOCAL BUS			AUTO			TOTAL ENERGY SAVINGS (10^{12} BTU)
	CHANGE IN PASSENGER MILES (10^9)	CHANGE IN VEHICLE MILES (10^9)	CONTRIBUTION TO ENERGY SAVINGS (10^{12} BTU)	CHANGE IN PASSENGER MILES (10^9)	CHANGE IN VEHICLE MILES (10^9)	CONTRIBUTION TO ENERGY SAVINGS (10^{12} BTU)	
1977	13.5	.39	-12.3	-16.5	-8.68	133.6	121.3
1980	33.8	.96	-30.6	-34.5	-18.16	279.4	248.8
1985	57.5	1.62	-51.6	-57.5	-30.26	465.8	414.2
1990	79.8	2.25	-71.6	-79.8	-42.00	646.3	574.7

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATION

To promote increased use of bus transit, the following implementation strategies have been assumed:

- greater operating frequency
- greater area coverage
- improved routing
- exclusive bus lanes
- subsidized transit fares
- a parking surcharge.

A potential shift to bus transit was developed based upon improved levels of bus transit. The estimate does not account for the special implementation incentives, such as exclusive bus lanes, parking surcharges, and subsidized transit fares.

According to an analysis of the transportation control plan (TCP) in San Diego,[1] these types of strategies could induce about a five percent shift of person trips to bus transit in urban areas. Assuming the implementation strategies as postulated in the San Diego TCP, it is possible that a diversion up to about 10 percent could be achieved in major metropolitan areas. However, it is unlikely that major shifts could be achieved for local travel external to highly urbanized areas.

Maximum feasible energy savings are based upon assumptions of approximate demand for transit services and productive capacity. Since reasonable estimates of probable shift to bus under the TCP could not be made, it has been assumed, for this study, that the TCP implementation strategies would result in shifts to bus at least as high as the estimate. Without the incentives in the TCP, it is questionable whether the maximum case could be achieved. The estimated achievable savings are shown in Figure V-22.

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[1] PMM, 1973.

FIGURE V-22

SHIFT TO BUS IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	121	248	414	575	5025
2. Estimated Feasible	121	248	414	575	5025
B. Impacts (Millions of Dollars)					
1. Private Industry					
Bus Manufacturing	$ 350 m.	$ 350 m.	$ 350 m.	$ 350 m.	$ 4,900 m.
Bus Transit Added Revenues	$ 957 m.	$2001 m.	$3335 m.	$4628 m.	$ 40,477 m.
Bus Transit Annualized Capital cost	($ 46 m.)	($ 184 m.)	($ 414 m.)	($ 644 m.)	($ 4830 m.)
2. Private Consumer					
Savings	$ 198 m.	$ 414 m.	$ 690 m.	$ 958 m.	$ 8379 m.
3. Public Sector					
Government fare box subsidy	($ 239 m.)	($ 500 m.)	($ 834 m.)	($ 1157 m.)	($ 10,119 m.)
Balance of Payments	$ 38 m.	$ 79 m.	$ 133 m.	$ 184 m.	$ 1,607 m.
Gasoline Tax Loss	($ 98 m.)	($ 200 m.)	($ 335 m.)	(465 m.)	($ 4,044 m.)
4. Employment (Jobs)					
Bus Manufacturing	18400	18400	18400	18400	18400
Bus Transit	68400	143000	238200	330600	330600
5. Environment (Percent Reduction)					
CO Reduction	.051%	.121%	.408%	.605%	
HC Reduction	.032%	.085%	.100%	.164%	

IMPACTS

Private Consumer

Commuting and local driving costs -- including maintenance, gas, oil, parking, tolls, gas taxes (but not depreciation and insurance) -- average approximately 4.9¢ per mile for subcompact automobiles, 5.5¢ for compacts, and 6.4¢ for standard-size vehicles. Considering that many commuters own a second car expressly for commuting, operating and capital cost of 7¢ per mile costs, an average commuting operating and capital cost of 7¢ per mile has been assumed. Thus, for the single driver - the one most susceptable to using bus transit - commuting costs by bus are reduced by 1.2¢ per mile. Between 1977 and 1990, the cumulative commuter savings would be an estimated $8.4 billion dollars.

Public Sector

Most bus transit fares, especially in large cities, do little more than cover direct operating and administrative costs, and do not cover depreciation or capital for replacement and new vehicles plus other capital requirements. Under a program to provide greater incentive to use bus transit, parking taxes, tolls or other items may be instituted or raised to discourage auto traffic and to help reduce subsidy deficits. It is estimated that, in constant 1974 dollars, a new subsidy of approximately 10¢ per passenger, or 25 percent of fare box revenue could be required by 1977. The subsidy level has been assumed constant through 1990.

The avoidance of oil imports between 1977 and 1990 is estimated at $1.6 billion. Government gasoline tax losses would be approximately $4.0 billion between 1977 and 1990.

Scarce Materials and Resources

No significant materials/resources impacts are anticipated from implementation of this measure, as it relates to factors well within the scope of present technological and supply capabilities.

Quality of Life

While increased mass transit use entails some negative quality of life impacts, the overall impact of this measure should be significantly positive, especially since most of the implementation strategies (e.g., greater operating frequency and area coverage) are designed to make mass transit more convenient.

Mass transit riders avoid driving strain and are less subject to the carbon monoxide buildups which effect rush-hour drivers. Less time is lost searching for parking spaces in congested areas. Finally, the mass transit rider can benefit from alternative use of time in transit for reading and so forth.

On the negative side of bus transit use are the difficulties it can cause for travellers who do not have access to fast main line transit service or who, for other reasons, cannot take mass transit and must pay the higher parking tax suggested to implement this measure. For some, mass transit may mean slower, instead of faster transportation, with one or more annoying and time-consuming transfers. Crowded and poorly ventilated transit buses and trains are, of course, a source of discomfort to all. Inadequate or nonexistant shelter facilities at transit stations can prove uncomfortable.

In the balance, however, increased mass transit use will likely produce quality-of-life impacts that are more positive than negative; and as ridership increases, service can improve so that negative impacts can be minimized. It is significant to note that a California Poll study in early 1973[1] showed that even in automobile-dominated California, 62 percent of those persons surveyed indicated that they were in favor of building rapid transit lines, even at an increased tax cost of $100.00 per family.

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[1] Time Magazine, July 16, 1973.

Environment

Implementation of the increased mass transit measure could result in a reduction in total CO emissions of 0.05% in 1977; 0.12% in 1980; 0.47% in 1985; and 0.61% in 1990.

The impact on HC reductions is relatively small for this measure since buses emit more of these pollutants per BTU than automobiles. For 1977, .032% HC reduction is possible. This increases to .085% reduction by 1980; .100% for 1985; and .164% for 1990. It is significant that the emission reductions, both HC and CO, will occur in major metropolitan areas which experience the most severe air pollution. Air quality benefits may be expected to exceed the emission reduction ratios presented above.

Another environmental benefit of increased mass transit could be reduction of traffic congestion and noise as one bus can eliminate up to 25 rush-hour vehicles. Implementation could substantially contribute to relieving congestion problems.

Private Industry (Cost/Savings)

Manufacturers of buses and parts would be the biggest beneficiary of a shift to bus transit, aside from the transit industry itself. Assuming a cost of $50,000 per transit bus, annual bus sales would increase by approximately $350 million. Assuming that an average fare of $0.058/passenger mile is earned, the added fare tax revenues would climb dramatically from $957 million in 1977 to $4.6 billion in 1990. Annualized capital costs for new buses would cost bus transit companies an estimated $4.8 billion between 1977 and 1990 (at 10 percent, 15-year economic life).

Though many bus transit systems are publicly owned and operated, all bus companies are included under the private industry heading, for convenience.

Employment

Assuming that 50 percent of the purchase cost of a bus represents labor, new employment figures for transit bus manufacturing at $9,500 per employee is estimated at 18,400 new jobs to sustain production of 7,000 buses/year.

Using national averages of approximately 75 percent of farebox revenue as labor expense and $10,500 per transit company employee, new jobs created in public transit are estimated to range from 68,400 in 1977 to 330,600 in 1990.

Additional offsetting employment decreases due to a down or decline in the automotive and supporting industries occur. Data were not available to estimate this effect.

G. MODE SHIFTS IN INTERCITY PASSENGER TRANSPORTATION

1. Maximum Energy Savings

General Discussion

There are four major modes of intercity passenger transportation; automobiles, airplanes, buses, and passenger rail. Figure V-23 summarizes the 1970 energy and passenger mile relationships.

Figure V-24 shows the base case forecast for intercity passenger transportation. This forecast shows continued dominance of intercity transportation by automobiles with airplanes continuing to gain market share.

Air transportation is the most energy intensive mode followed by automobile transportation. Shifting intercity passenger transportation from these two modes to rail and bus has been proposed as a method of conserving energy. This analysis will consider two shifts: from air to rail and from auto to both rail and bus The following is a discussion of both these shifts.

Shifts from Air to Rail Passenger Transportation

1. Background

Over the past twenty years, the trends in energy consumption for domestic intercity transporting of passengers by rail and air have been increasingly divergent. From slightly over 100 trillion BTUs for both in 1955, air usage rose to almost 900 trillion BTUs in 1971, while rail consumption dropped to approximately 13 trillion in 1971.[1] A shift in usage between these two modes is the reason for this phenomenon. However, since the energy intensity of rail service is significantly lower than for air service, a pronounced reversal in this trend is surely a worthwhile energy conservation measure.

In analyzing the possibilities of reversal, it is wise to recognize the changes which have occurred in the recent past to

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[1] Mutch, 1973.

FIGURE V-23

INTERCITY PASSENGER TRANSPORTATION

MODE	PASSENGER MILES (10^9 P.M.)	ENERGY INTENSITY (BTU/P.M.)	ENERGY CONSUMPTION (10^{12} BTU)
AUTO	1026	3400	3489
AIR	119	8400	1000
RAIL	11	2900	32
BUS	25	1600	40
TOTAL	1181	3862	4561

Sources: Hirst, Eric Energy Intensiveness of Passenger and Freight Transport Modes 1950-1970, ORNL-NSF-EP-44, April, 1973

FIGURE V- 24

INTERCITY BASE CASE PASSENGER FORECAST

(10[9] Passenger Miles)

YEAR	AUTO[1]		AIRWAY[2]		BUS[3]		R.R.[4]		TOTAL
	PM	%	PM	%	PM	%	PM	%	
1970	1026[5]	86.9	119[5]	10.1	25[5]	2.1	11[5]	.9	1181
1977	1267	85.1	180	12.2	29	1.9	12	.8	1488
1980	1350	83.7	220	13.6	31	1.9	12	.7	1613
1985	1579	81.5	310	16.0	34	1.8	13	.7	1936
1990	1880	79.5	434	18.3	38	1.6	13	.6	2365

1. Allocation from Chase Econometric study
2. Assumed 7.0% growth rate
3. Assumed 2.1% growth rate
4. Assumed 1.0% growth rate
5. Source: Hirst, Eric; Energy Intensiveness of Passenger and Freight Transportation, 1950-1970, ORNL-NSF-44, April 1973

assist in defining the constraints on the maximum feasible shift. Jet travel has become commonplace and total trip time is quite low in comparison to other existing modes, particularly over long distances. Total trip time is one of the major determinants of mode selection for intercity transport, particularly for business related travel. Therefore, if one is to be successful in mode shifting from highly energy intensive air travel in the intercity category, alternative modes must be competitive on a time basis. The least energy intensive substitute is the bus, but it is not very competitive, except over very short distances. For instance, for a 200 mile trip, buses are estimated to approximately double total trip time.[1] Also, future reductions in trip time are not available. The relative slowness is especially apparent now that a 55 mile/hour speed limit has been imposed. Even with the lower fares related to bus service, it is difficult to believe that they offer an acceptable alternative beyond 100 to 150 miles. High Speed Rail (HSR) offers the best alternative which should be technically available on a widespread basis in the period of concern to this study. With a shift from air to rail, trips of 400 miles would increase approximately one hour (from 3 to 5 hours). This would seem to represent a limit on public acceptability for mode shifting away from airlines and, therefore, was established as the maximum feasible condition assumed in this study.

2. The Approach

Energy savings related to shifting all former airline passenger trips of 400 miles or less to rail cannot be simply estimated by applying energy intensity for both to airline passenger miles for passenger trips under 400 miles. Many under 400 mile passenger trips are related to flights of longer total distance and, therefore, savings would drastically be overestimated. Historically, two approaches have been taken in calculating maximum savings related to a specified passenger trip limit. Mutch calculated the savings from eliminating all aircraft flights of a total distance equal to or less than the passenger trip limit.[1] This can be done quite accurately, but additional savings are feasible. Additional takeoff and landing maneuvers which are highly energy intensive could be reduced by eliminating intermediate stages of less than 400 miles on longer airline flights. Recognizing the additional savings available, Pilati estimated savings based on elimination of stages under the passenger trip limit.[2] This approach also has problems, since it is difficult to estimate what percentage of stages could be eliminated. Certainly not all stages can be eliminated. Part of the energy saved would be required to maintain airline flights over 400 miles from which stages are eliminated. Pilati picked 40% in his study for purposes of example and as the following analysis will show, this is within the range of maximum feasible savings.

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[1] Mutch, 1973.

3. The Results

Information is readily available for airline flights under 400 miles. Passenger miles related to flights under 400 miles were determined and baseline projections were made assuming a growth rate of 7% Energy intensity for aircraft was assumed constant, based on the assumption of a leveling off of the trend in decreasing airline load factors. Savings ranged from 163 trillion BTUs in 1977 to approximately 422 trillion BTUs in 1990, based on rail reducing its energy intensity from present levels to 1550 BTUs/P.M. (See Figure V-25). Increasing of the load factor from the present level of below 40% should be a direct result from the shift to this travel mode.

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[1] Mutch, 1973

[2] Pilati, 1974

Figure V-26 presents the savings employing Pilati data and approach. Savings are slightly larger than under the first approach. One first inclination is to say that this additional savings accounts for that which could be attributed to elimination of stage connected to airline flight over 400 miles previously mentioned. However, on close inspection of Figure V-26 one realizes that the larger values resulting from the higher aircraft energy intensity assumed by Pilati. The number of passenger miles shifted in the second approach is actually less. The basic difference for aircraft energy intensity could not be readily explained. Time requirements of this study did not allow for the extensive investigation to resolve the difference. However, values are close enough that a reasonably tight range of maximum feasible savings can be estimated. They are given in Figure V-27.

Shifts from Automobile to Rail and Bus

As with public transit, the problem of hypothetical prior data exists. The literature does not calculate a maximum technically feasible energy savings, or even a non-speculative practically feasible energy savings, but instead uses hypothetical "if...then" scenarios. Examples are Hirst,[1] who projected a shift of one-third of auto passenger miles to rail and bus, and Millaris and Strombotne,[2] who projected a 50% shift of passenger miles.

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[1] Hirst, 1973.

[2] Millaris and Strombotne, 1973.

FIGURE V-25

ENERGY SAVINGS FROM SHIFTS IN TRAVEL MODES FROM AIRPLANE TO HIGH SPEED RAIL BY ELIMINATING AIRLINE FLIGHTS UNDER 400 MILES

(growth at 7% annually)

	1977	1980	1985	1990
TOTAL DOMESTIC AIRLINE PASSENGER MILES WITHOUT CONSERVATION (10^9 P.M.)	180.39	220.90	309.94	434.69
PASSENGER MILES TRANSFERRED TO RAIL BY ELIMINATING ALL AIRLINE TRIPS LESS THAN 400 MILES (10^9 P.M.)	18.14	22.62	32.67	47.08
AIRLINE (BTU/P.M.) ENERGY INTENSITY	10,511	10,511	10,511	10,511
AIRLINE ENERGY ELIMINATED (10^{12} BTU)	190.67	237.76	343.39	494.86
RAIL ENERGY INTENSITY (BTU/P.M.)	1,550	1,550	1,550	1,550
INCREASED RAIL ENERGY (10^{12} BTU)	(28.12)	(35.06)	(50.64)	(72.97)
NET DIFFERENCE (10^{12} BTU)	162.55	202.70	292.75	421.89

Source of Method (Mutch)

FIGURE V-26

ENERGY SAVINGS FROM SHIFTS IN TRAVEL MODES FROM AIRPLANE TO HIGH SPEED RAIL BY ELIMINATING ONE-HALF OF THE AIRLINE STAGES UNDER 400 MILES

(growth at 7% annually)

	1977	1980	1985	1990
TOTAL DOMESTIC AIRLINE PASSENGER MILES (10^9 P.M.)	180.39	220.90	309.94	434.69
PASSENGER MILES TRANSFERRED BY ELIMINATING ONE-HALF STAGES UNDER 400 MILES (10^9 P.M.)	15.51	19.00	26.65	37.38
AIRLINE ENERGY INTENSITY (BTU/P.M.)	13,159	13,159	13,159	13,159
AIRLINE ENERGY SAVED (10^{12} BTU)	204.10	250.02	350.69	491.19
RAIL ENERGY INTENSITY (BTU/P.M.)	1,550	1,550	1,550	1,550
INCREASED RAIL ENERGY (10^{12} BTU)	(24.04)	(29.45)	(41.30)	(57.44)
NET DIFFERENCE (10^{12} BTU)	180.06	220.57	309.39	433.25

Source of Method (Pilati)

FIGURE V-27

RANGE OF MAXIMUM PROJECTED ENERGY SAVINGS FROM SHIFTS IN TRAVEL MODES FROM AIRPLANE TO HIGH SPEED RAIL FOR PASSENGER TRIPS UNDER 400 MILES

YEAR	1977	1980	1985	1990
Savings (10^{12} BTU)	180-216	220-264	309-371	433-520

The passenger absorption capacity of the intercity bus and rail modes represents the primary physical limit of the mode shift. This constraint, however, in the long run is not the primary inhibition on the transfer of passengers from auto travel to bus and rail. The future evolution of the demand for the flexibility, convenience and privacy of private automobile travel will determine the extent to which public transportation modes will be able to grow. In this sense, what determines the amount of use of public intercity transportation is its perceived ability to provide competitive services. There is no technical reason why both bus and rail service could not expand in time to any given level of demand.

One innovative method of stimulating rail traffic is the proposed auto train. This is a passenger train which also carries along the cars of the passengers. It could offer both the ease of not having to drive and the freedom of having one's own car at the destination.

Since the feasibility constraint on intercity bus and rail passenger transportation is essentially the capacity of the equipment, a problem is faced by the forecaster of mode shift potential. The amount of expansion of capacity depends primarily upon the demand expectations of the industries involved. This is a function of many imprecisely known factors: management competence, future government actions, public preferences, competitive actions, economic conditions, etc. There really is no unique analytically derivable maximum potential. What one can do is develop a scenario under which a reasonable plan for rail and bus expansion is possible and then estimate savings based on the scenario. The prior literature has reached the "scenario development" stage, but not the "planning" stage.

It is assumed that a program of expansion of bus and rail modes would entail both the efficient utilization of existing equipment and consistent and rapid growth in new equipment. It would combine both raising load factors and investment in new plant and equipment. Especially of importance would be the need to upgrade railroad tracks throughout the country so that heavy volumes of passenger traffic could move with safety and speed.

Both intercity bus and rail passenger transportation have load factors below their practical limits; 46% for bus and 37% for rail. Increased numbers of passengers produced by stimulating demand for these two modes could partly be taken up by increasing the load factor. The maximum practical load factor is assumed to be less than 100%. It can be expected that as demand expands, total capacity will also. Thus, the ability to fill to vehicle capacity is counterbalanced. Also, as part of a program to entice passengers to rail and bus, the transportation companies may not want 100% load factors. At very high load factors, potential passengers have much higher possibilities of being "bumped" off a seat or simply not getting one. This could decrease the demand for intercity rail or bus service. A 70% maximum load factor is assumed in this study. This alone represents a 52% increase in passengers for intercity buses and an 89% increase for railroads.

If, in addition to increasing load factors, we assume that capacity expands at a swift and steady rate, additional energy savings can be seen to arise. In this study, a 12.5% growth rate in passenger miles for both bus and rail is assumed starting in 1975 and lasting throughout the period under discussion. This expansion rate is quite arbitrary, but consistent in magnitude with other recent modal shift trends in transportation, notably that for TOFC.

Figure V-28 shows projected intercity auto traffic. It is from this pool of passenger miles that rail and bus passenger miles would be generated in a mode shift. Figure V-29 represents base case energy consumption for all three modes considered. If all auto traffic were shifted equally to bus and rail, the following net energy savings could be realized:

Year	Savings (10^{12} BTU)
1977	2618
1980	2739
1985	3000
1990	3480

This amount of energy savings clearly exaggerates possible growth in bus and train travel. Assuming the 70% load factors and 12.5% per year growth in capacity as the rapid growth rate would yield a more realistic estimate of the maximum energy savings that could be practically expected. Figure V-30 shows the passenger mile and energy consumption relationships after such rapid growth in capacity. Figure V-31 shows the components of the passenger mile shifts and energy savings. It shows energy savings in trillion BTUs of 96, 158, 336, and 614 in 1977, 1980, 1985 and 1990 respectively. It should be realized that this maximum energy savings is not really a maximum technical savings, but rather represents an estimate of the maximum which could be expected under conditions of strong growth and high load factor.

FIGURE V-28

FORECAST OF INTERCITY AUTOMOBILE ENERGY EXPENDITURE

YEAR	PASSENGER MILES (10^9)	VEHICLE MILES (10^9)	ENERGY INTENSITY (Btu/PM)	ENERGY USE[1] (10^{12} Btu)
1977	1267	495	3381	4284
1980	1350	527	3343	4513
1985	1579	617	3214	5075
1990	1880	734	3165	5951

[1] Based upon E. Hirst, Direct and Indirect Energy Requirements for Automobiles, ORNL-NSF-EP-64, February 1974. These values are decreased by an amount proportional to the relative decrease in miles per gallon forecast by the Automobile Fuel Consumption Study of Chase Econometrics, Inc. for each year. (1977 fuel consumption is at the rate of 15.7 mpg for intercity driving).

FIGURE V- 30

INTERCITY AUTO, BUS AND RAIL

TRAFFIC AND ENERGY

CONSERVATION CASE

	MODE							
	RAIL		BUS		AUTO		TOTAL	
YEAR	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)
1970	11[1]	32[1]	25[1]	40[1]	1026[1]	3488[1]	1062[1]	3560[1]
1977	26	41	48	51	1234	3989	1308	4081
1980	37	58	70	74	1286	4114	1393	4246
1985	69	108	130	137	1420	4365	1626	4610
1990	130	204	243	257	1558	4719	1931	5180

Source: [1] Hirst, Eric, Energy Intensiveness of Passenger and Freight Transportation 1950-1970, ORNL-NSF-44, April 1973.

FIGURE V-29

INTERCITY AUTO, BUS AND RAIL

TRAFFIC AND ENERGY

BASE CASE

	MODE							
	RAIL		BUS		AUTO		TOTAL	
YEAR	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)	TRAFFIC (10^9 PM)	ENERGY (10^{12} Btu)
1970	11[1]	32[1]	25[1]	40[1]	1026[1]	3488[1]	1062[1]	3560[1]
1977	12	35	29	46	1267	4096	1308	4177
1980	12	35	31	50	1350	4319	1393	4404
1985	13	38	34	54	1579	4854	1626	4946
1990	13	38	38	61	1880	5695	1931	5794

Source: [1] Hirst, Eric, Energy Intensiveness of Passenger and Freight Transportation 1950-1970, ORNL-NSF-44, April 1973.

FIGURE V-31

MAXIMUM FEASIBLE
ENERGY SAVINGS
AND
PASSENGER MILE SHIFTS
UNDER
12.5% GROWTH SCENARIO

	MODE							
	RAIL		BUS		AUTO		TOTAL	
YEAR	CHANGE IN TRAFFIC (10^9 PM)	ENERGY SAVINGS (10^{12} Btu)	CHANGE IN TRAFFIC (10^9 PM)	ENERGY SAVINGS (10^{12} Btu)	CHANGE IN TRAFFIC (10^9 PM)	ENERGY SAVINGS (10^{12} Btu)	CHANGE IN TRAFFIC (10^9 PM)	ENERGY SAVINGS (10^{12} Btu)
1977	14	- 6	19	- 5	- 33	107	0	96
1980	25	- 23	39	- 24	- 64	205	0	158
1985	56	- 70	96	- 83	-159	489	0	336
1990	117	-166	205	-196	-322	976	0	619

2. Achievable Savings and Impacts

ENERGY SAVINGS REALIZATIONS

The implementation strategies chosen to decrease intercity automobile travel and increase use of buses and trains include increased common carrier frequency and range and quality of service. These improvements would be attained through legislative changes and economic incentives. Assuming 100 percent effectiveness of the legislative and economic strategies, success would be constrained primarily by common carrier capacity to penetrate the intercity automotible market and the capability of the common carriers to meet and service resulting increased market demand.

Modal shift would be influenced by the following factors, in generally decreasing order of importance:[1]

Business Travel	Other Travel (e.g. Discretionary, Pleasure, Vacation)
1. Frequency of Service	1. Economics
2. Portal-to-Portal Time (speed)	2. Convenience
3. Reliability	3. Frequency of Service
4. Convenience	4. Comfort
5. Comfort	5. Reliability
6. Economics	6. Speed

A better understanding of these factors, their relative importance and trade-offs and the ability of private industry, government, and AMTRAK to meet expectations or requirements of the traveling public will allow better estimates of the degree of passenger shifts achievable.

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[1] FRA, 1973.

A diversion of 20 percent of intercity auto passenger miles per year would increase surface common carrier passenger transportation demand by 340 percent[1] (based on 1970 data). In 1974, AMTRAK reported spot increases of up to 40 percent over 1973, which placed the railroad agency in an extremely difficult position to meet demand in certain traffic lanes.[2] While AMTRAK is currently accelerating the rebuilding of older passenger railroad cars and buying new equipment, this recent experience indicates 1) that the public is willing to use surface common carriers, and 2) that AMTRAK could not accommodate high short-run growth. AMTRAK is confident, however, that the situation will be improved by 1975.

Similar traffic problems were not experienced by intercity bus carriers, indicating their greater capacity, flexibility, and ability to react to increased demands.

With the recent demonstration of public willingness to take to the train or bus, providing capacity and maintaining comfort and service appear to be the major overriding constraints to the desired modal shift.

Since the Interstate Highway network is largely complete and only marginal improvements are likely in improving the automobile as a preferred method of intercity travel, the outlook of passenger common carriage by bus and rail is bright. Limitations appear to be those of growth and financial resources. Bus companies are not as capital intensive as rail, and appear able to generate needed cash flow for moderate growth. AMTRAK, which is both capital intensive and unprofitable, has required governmental backing and support. In 1977, a five percent shift to bus/rail appears possible and manageable from a marketing viewpoint. By 1990, holding the same market viewpoint, a 15%

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[1] TSC, 1973.

[2] *Railway Age*, 1974.

shift form highway to bus/rail appears feasible since neither the maximum 1990 market nor the common carrier growth capacity would be exhausted.[1]

Based on this discussion and supported in part by a related Transportation System Center Study,[2] an unconstrained estimate assuming increased frequency and quality service of feasible modal shift from automobile to bus/train is as follows:

Year	Percent of Intercity Passenger Miles Shifted to Bus/Rail - Market Feasibility
1977	5
1980	8
1985	12
1990	15

Assuming the above diversion, incremental passenger mile growth by bus/rail would be as follows:

Year	Automobile Passenger Miles (10^9)	Percent Modal Shift	Common Carrier Increase in Passenger Miles (10^9)		
			Total	Bus	Rail
1977	1,267	5	63.4	44.8	18.6
1980	1,350	8	108.0	77.9	30.1
1985	1,579	12	189.5	137.0	52.5
1990	1,880	15	282.0	210.0	72.0

Assuming a potential 125,000 miles per year utilization for each bus, with 40 seats per bus, and 200,000 miles per year utilization for rail passenger cars, with 54 seats per rail passenger car and assuming a 70 percent load-factor, the added number of vehicles required to meet potential demand is as follows:

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[1] PMM&Co. professional staff judgment.

[2] TSC, 1973.

Year	Cumulative Vehicles Needed to Handle Incremental Modal Shift		Cumulative Locomotives
	Bus	Rail	
1977	12,800	2,500	300
1980	22,200	4,000	500
1985	39,200	6,900	900
1990	60,000	9,500	1,200

If enough buses and rail passenger cars could be built to satisfy estimated market potential, energy savings are estimated as follows:

Potential Energy Savings

	1977	1980	1985	1990
Estimated potential market shifts to bus/rail	5	8	12	15
Estimated passenger miles diverted to bus/rail ($\times 10^9$)	63.4	108.0	189.5	282.0
Average Bus/Rail BTU/PM[1]	1,195	1,193	1,192	1,180
Auto BTU/PM	3,381	3,343	3,214	3,165
Maximum energy savings from marketing viewpoint-BTU$\times 10^{12}$	139	232	383	560

However, the above maximum energy savings estimates are not feasible because of capacity constraints in the equipment manufacturing industry. In addition, both bus and train manufacturing industries are hampered by materials and parts shortages.

However, assuming delayed equipment retirements, an increase of 500 new buses and 250 rail passenger cars per year could be achieved based upon estimated production levels. Assuming an accelerated net fleet growth of 10 percent per year (base 1974), the practical limit of feasible new capacity would be as follows:

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[1] Weighted average based upon estimated diversion from automobile to bus and rail.

Year	Cumulative Net Fleet Additions			Additional Passenger Miles ($\times 10^9$) Handled from Auto[1]			Percent Modal Shift	Percent of Potential Market		
	Bus	Rail Cars	Rail Locomotive	Bus	Rail	Total		Bus	Rail	Total
1977	1,820	1,100	132	4.4	8.3	12.7	1.0	10	45	20
1980	4,240	2,550	319	10.8	19.3	30.1	2.2	14	64	28
1985	10,200	6,100	796	28.7	45.1	73.8	4.6	21	86	40
1990	19,800	11,900[2]	1,485	58.3	89.0	147.3	7.8	28	124[2]	52

By 1990, possible capacity would exceed market potential.

As a result of new equipment production constraints, intercity modal shift potential as shown on the previous page could be limited to approximately 20 percent of 1977 potentia; 28 percent of 1980 potential; 40 percent of 1985 potential; and 52 percent of 1990 potential. The estimated feasible energy savings are shown in Figure V-32.

IMPACTS

Private Consumer Cost/Savings

With automobile out-of-pocket operating costs ranging between 3 and 5 cents per mile depending on the size and age of vehicle (among other things), common carrier transportation is merely a break-even situation with one person. With two or more, it is often cheaper to drive, assuming the driver would own or continue to own a car, regardless of intercity mode of travel.

Dollar estimates of the added consumer cost is estimated at almost $13 billion between 1977 and 1990. The estimate assumes $.05 passenger mile common carrier cost and $.018 passenger mile automobile cost (at 2.2 persons/automobile).

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[1] Excludes passenger mile growth not obtained from automobile: 1974 Base = 27×10^9 PM for bus, 12×10^9 for rail.

[2] Capacity exceeds estimated market potential.

With the per passenger mile cost of common carrier about the same as out-of-pocket per vehicle mile cost by automobile, economics greatly favor the automobile when more than two passengers are involved. Since intercity travel alone is rarely the reason for automobile ownership, increased use of common carrier for intercity transportation should not result in measurable automobile ownership reduction.

Public Sector Cost/Savings

To maintain rail passenger service, the government has provided AMTRAK with over $200 million annually in subsidies or guaranteed loans. By the end of 1975, this annual expense will increase to nearly one-half billion dollars. While less than $200 million is required to underwrite operating losses, the balance still represents a sizeable annual investment in capital and assets for improved and continued service. These expenditures have stimulated new rail passenger ridership. At least 500 million in federal subsidies would be required to obtain the increased service levels called for in the measure.

Not all new ridership has been diverted from automobile traffic. Overly subsidized rail operations could jeoparidze the profitability and growth of privately owned bus common carriers and detract from the most energy efficient mode of intercity transportation. However, because of the present profitability of intercity bus, no federal subsidy has been assumed.

Government expenses for new technology in intercity transportation include funds for the development of better propulsion systems, improved cushioning systems, and safety systems for passenger cars and trucks. Also, the government is subsidizing the study of new, high technology systems, such as magnetic levitation ("mag-lev"), linear induction propulsion systems, and other exotic high-speed systems. Aside from contracts with industry and manufacturers, most work is being conducted through the Federal Railroad Administration. These expenditures, while related to intercity passenger transport, were not counted as cost impacts since the modal shifts claimed are not related to the development or introduction of new technology. Finally, an estimated $1.6 million in gasoline tax premiums would be lost.

Scarce Materials and Resources

Steel, castings and forgings while more productive in commercial transportation use (in terms of pounds per passenger and/or utilization and life), are allied more closely with the automobile manufacturing market. Because of the automobile orientation and the present short supply of these materials, the steel, casting and forging industries have not responded to the full demand of other markets. For example, bus transmissions are currently on allocation. These problems are expected to continue into 1975, with some easing by 1980.

Quality of Life

The shifting of intercity travel modes away from the automobile entails several positive as well as negative quality-of-life impacts. By opting to use common carrier over automobile, full control of arrival and departure time is lost. While common carriers attempt to minimize inconvenience and discomfort factors (e.g., reliability) to penetrate the automobile transportation market, there are relatively few instances where common carrier modes can, in fact, match automobile travel on every point. When a traveler is induced to change from automobile to common carrier by means of economic incentives or by increasing schedule frequency, less critical quality factors, such as overall convenience and travel time, will probably suffer.

There are positive quality-of-life impacts associated with modal shifting which at least partially compensate for the negative impacts. Common carrier travelers benefit from a higher level of travel safety. In addition, removing the strain of driving from individuals can, for many people, add to the pleasure of the journey. Finally, an added benefit, particularly for business travelers, is the use of travel time for purposes other than driving, e.g., reading and writing.

Environment

For modal shifts from cars to buses, there will be a decrease in CO emissions from autos and an increase in bus-produced CO. The net result, however, is a lowering of CO. While major problems are associated with intraurban travel, reduced intercity automobile travel can result by 1977 in the elimination of 16.6 million pounds of CO. The net impact (.01% of all CO produced) is fairly small.

The transportation sector accounts for around 60 percent of man-made hydrocarbon (HC) emissions. The reduction in HC produced (HC decreases with increased bus use) would be 1.85 million pounds in 1977 or 0.007% of all hydrocarbons, 4.25 million pounds (0.02%) in 1980, 13.2 million pounds (0.07%) in 1985, and 13.5 million pounds (0.08%) in 1990. As with the CO reduction impact, HC reduction is relatively small for this measure.

It should also be noted that the most severe air pollution problems occur in major urban areas and that emission reductions in intercity transportation will probably produce little air quality improvement.

Private Industry Cost/Savings

Assuming 1974 constant costs: new buses at $75,000 each, new passenger railorad cars at $350,000 each, and new diesel locomotives at $500,000 each (4,000 h.p.), the cumulative incremental fleet costs to handle modal shift are estimated as follows:

Year	Cumulative Incremental Bus Capital Requirements ($ x 10^6)	Cumulative Capital Rail Cars ($ x 10^6)	Incremental Rail Requirements Locomotives ($ x 10^6)	Total Cumulative Capital ($ x 10^6)
1977	137	385	69	591
1980	318	893	159	1,370
1985	765	2,135	381	3,281
1990	1,485	4,165	744	6,394

Costs for individual years are estimated in Figure V-12. Passenger revenues are estimated at $.05 per passenger mile for rail and $.045 per passenger mile for bus, in constant 1974 dollars.[1,2]

Employment

The average number of new jobs created in the transportation industry and the manufacturing of new equipment is estimated at 39,000 by 1990.[3]

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[1] AAR, 1974.

[2] NAMBO, 1973.

[3] Assumes 50% of operating cost/revenue is labor; hence, jobs equal cost x .50 ÷ mean income.

FIGURE V-[illegible]

INTERCITY PASSENGER MODE SHIFT IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	2,618	2,739	3,000	3,480	41,262
2. Estimated Feasible	25	60	138	263	1,769
B. Impacts (Millions of Dollars)					
1. **Private Industry Revenues**					
Rail/Bus Manufacturing	$197m	$260m	$382m	$623m	$6,394m
Transportation industry	$613m	$1,451m	$3,547m	$7,074m	$43,176m
Transportation Industry -			($ 98m)		
Capital Cost	$ 23m	($ 54m)	($ 98m)	($172m)	$(1,267m)
2. **Private Consumer Added Cost**	($365m)	($399m)	($2,182m)	($4,240m)	($12,968m)
3. Public Sector					
Government Rail Subsidy	($500m)	($500m)	($500m)	($500m)	($7,000m)
Balance of Payments	$ 8m	$ 19m	$44m	$85m	$ 533m
Gasoline tax loss	($ 34m)	($ 84m)	($202m)	($267m)	($1,842m)
4. **Employment (Jobs)**					
Rail/Bus Manufacturing	2,600	3,400	4,400	6,500	6,500
Transportation Industry	0	12,900	19,300	32,500	32,500
5. **Environment (Percent Reduction)**					
Reduced CO	.011%	.029%	.126%	.282%	
Reduced HC	.0067%	.018%	.073%	.076%	

H. REDUCED SPEED LIMITS ON HIGHWAYS

1. Maximum Energy Savings

General Discussion

One of the first official government actions in the wake of the Middle East oil embargo was the reduction of speed limits on interstate and main rural roads to 55 miles per hour. Energy savings are expected to result from the decreased rate of consumption of fuel per vehicle mile.

Energy savings may also result if lower speed limits induce people to travel less. Figure V-33 shows that there has been a decrease in travel on main rural roads since about December, 1973. If this lowered trend continues, about a 10% savings in both vehicle miles and fuel from the prior trend would occur that could be attributable to decreased vehicle miles alone. What portion of this savings could be accounted for by decreased speed limits rather than other factors such as shortages and increased prices is, however, uncertain.

The reduction in travel may shift some travel from slower autos to other modes, such as airplanes and trains. To the extent that travel is shifted to less energy intensive modes, such as trains, further energy is saved. Similarly, energy is lost as passengers may shift to more airplane flights. An analysis of mode shifts due to decreased speed limits would have complex ramifications and is not considered here. This analysis considers only the savings resulting from reduced speeds over which an assumed fixed number of vehicle miles are driven.

The effective enforcement of lowered speed limits is also expected to have a great effect on safety. According to the FHWA[1], the accident rate should decrease slightly while even larger reductions

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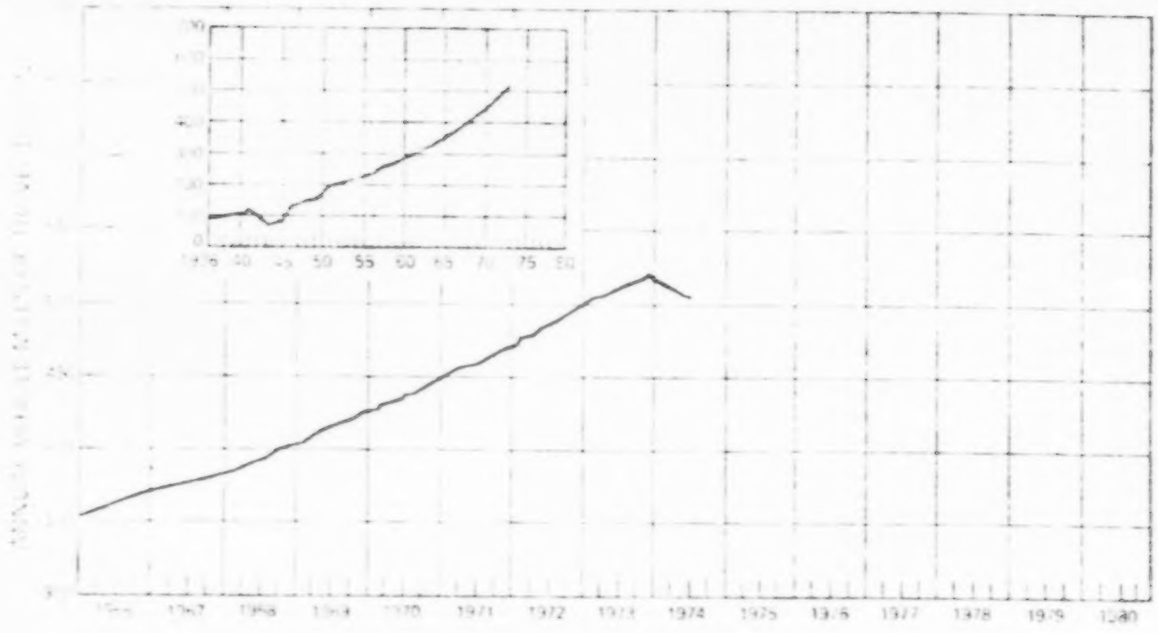
[1] French, 1974

FIGURE V-33

ANNUAL TRAVEL ON MAIN RURAL ROADS FOR 12 MONTH PERIOD IN MONTH SHOWN



Source: Federal Highway Administration, "Traffic Volume Trends." June 1974.

should occur in the fatality rate. The causes of this increased traffic safety on main rural roads and freeways is threefold. First, the injury rate is minimum between 50 - 60 mph; being about half that for 75 mph[1]. Second, the lowering of speed limits decreases variations in vehicle speeds. Third, the severity of injuries at 50-55 mph is much less than at higher speeds.

Calculation of Vehicle Miles Travelled

Total vehicle miles on main roads for each year are recorded by the FHWA.[2] Not all of the vehicle miles, however, are travelled under circumstances which allow travel above 55 mph. On many occassions meterological conditions, such as heavy rain or traffic congestion may limit vehicle speeds. Significant amounts of travel speed above 55 mph are only possible in the absence of such conditions resulting in what is termed "free flow" traffic. French has estimated the amount of free flow traffic and its total energy consumption on main roads.[3] This is detailed in Figure V-34 for 1972. Forecasts for 1977, 1980, 1985 and 1990 are shown in Figure V-35. These tables also contain projected fuel consumption estimates to be explained below.

As stated earlier, the reduced speed limits apply only to travel on interstate and main roads. With any speed limit, not all travel is at that limit. There is instead a distribution of vehicle speeds on the roadway. Many states gather information on vehicle speeds and this is recorded and tabulated by the Department of Transportation. DOT publishes this data annually as a Federal Highway Administration Bulletin.[4]

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[1] French, 1974

[2] FHWA, 1973b

[3] French, 1974

[4] FHWA, 1973-74

FIGURE V-34

FUEL USE AND VEHICLE MILES OF TRAVEL
1972

VEHICLE	VEHICLE MILLS		FUEL USE	
	TOTAL 10^6	FREE FLOW 10^6	TOTAL 10^6 Gallons	FREE FLOW 10^6 Gallons
PASSENGER CARS	1,003,498	502,009	73,463	29.192
SINGLE UNIT TRUCK	213.122	122,861	22,118	11,675
COMBINATIONS	46,613	26,877	8,600	6.619
BUSES	5,109	2,774	881	556
ALL VEHICLES	1,268,342	654,521	105,062	48.042

Source: French, A., and Bishop, H., "Analysis of Fuel Saving Through Reduced Speed Limits", Federal Highway Administration, April, 1974

FIGURE V-35

BASE CASE PROJECTION OF FREE FLOW TRAFFIC

VEHICLE	ITEM	1972	1977	1980	1985	1990
Passenger Cars	Vehicle Miles x10^6 Fuel (Gallonsx10^6)	502,009 29,192	623,423 36,252	709,938 41,283	881,634 51,267	109,485 63,666
Single Unit Trucks	Vehicle Miles x10^6 Fuel (Gallons x10^6)	122,861 11,675	152,576 14,498	173,749 16,511	215,770 20,504	267,951 25,463
Combinations	Vehicle Miles x10^6 Fuel (Gallons x10^6)	26,877 6,619	33,377 8,220	38,009 9,361	47,201 11,625	58,617 14,436
Buses	Vehicle Miles x10^6 Fuel (Gallons x10^6)	2,774 556	3,445 690	3,923 786	4,872 976	6,050 1,212
ALL VEHICLES	Vehicle Miles x10^6 Fuel (Gallons x10^6)	645,521 48,042	801,645 59,661	912,891 67,941	1,133,670 84,372	1,407,846 104,778

Projected at 4.33% increase per year, a continuation of historical trends.

The data measured by the state is only recorded during good weather in non-congested traffic. Then it represents a good estimate of a distribution of "free flow" traffic. This analysis will use data from 1972 as a baseline distribution of vehicle speeds because that year was the last which fully preceded the popular awareness of the "energy crisis". This distribution of vehicle speeds is assumed to remain constant in the base case forecasts of vehicle miles by speed interval. Average speed on main roads for all types of vehicles has been increasing over the past 10 years, but this rate of increase has been slowing in recent years.[1] Thus the assumption of a constant distribution of speeds projects that the slowdown in the rate of speed increase will evolve into the steady state situation of the constant distribution.

Figure V-36 shows the distribution of free flow vehicle miles by forecast year and vehicle speed for different types of vehicles. This distribution was calculated by French[2] based on speed distribution information.[3]

3. Calculation of Energy Saving

Estimates for the rate of fuel consumption within each speed range are also contained in Figure V-36. Total fuel consumption within each vehicle type speed range category is the quotient of vehicle miles divided by miles per gallon. It should be noted that no distinction is made between gallons of deisel oil and gasoline fuel because of their approximately equivalance in BTU value. Rates of fuel consumption for single unit trucks and combination trucks are based on a FHWA study.[4]

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[1] FHWA, 1973-74

[2] French, 1974

[3] FHWA, 1973-74

[4] Claffey, 1971

FIGURE V-16

VEHICLE SPEEDS AND FUEL CONSUMED - 1972

VEHICLE	ITEM	UNDER 55 MPH	55-60 MPH	60-65 MPH	65 MPH & OVER
Passenger Car	Vehicle Miles x 10^6 Fuel (Gallons x 10^6) Average MPG	125,502 6,437 19.50	95,382 5,284 18.05	100,402 5,923 16.95	180,723 11,548 15.65
Single Unit Trucks	Vehicle Miles x 10^6 Fuel (Gallons x 10^6) Average MPG	54,058 4,491 12.04	33,172 3,202 10.36	20,887 2,229 9.37	14,744 1,753 8.41
Combinations	Vehicle Miles x 10^6 Fuel (Gallons x 10^6) Average MPG	11,626 2,320 5.09	7,257 1,833 3.96	4,569 1,376 3.32	3,225 1,090 2.96
Buses	Vehicle Miles x 10^6 Fuel (Gallons x 10^6) Average MPG	777 92 8.45	338 68 5.70	638 143 4.47	971 253 3.84

Source: French, A, and Bishop, H. "Analysis of Fuel Savings Through Reduced Speed Limits", ederal Highway Administration, HHP-40, April, 1974.

Rates of fuel consumption for automobiles are calculated by Cope.[1] French estimates rates of fuel consumption for buses in his report.[2] The numbers used in this report were developed by French[3] based upon the above sources.

Figure V-37 shows the percent fuel savings that would have resulted in 1972 if all vehicles which exceeded 55 mph reduced their speed to the 50-55 mph range. The actual fuel consumption for vehicles at speeds above 55 mph is calculated. Given a constant total of vehicle miles, the amount of fuel that would have been expended at 50-55 mph is then calculated. The total fuel savings is the difference between these two values.

As a last step in this figure, the percentage savings of total fuel consumed by each vehicle (from Figure V-37) in 1972 is calculated. This percentage savings is then projected to remain constant over the forecast years and results in the energy savings shown in Figure V-38. As can be seen in this figure, 928, 1057, 1310, and 1630 trillion BTU's of energy are saved in 1977, 1980, 1985 and 1990 by full enforcement of 55 mph. speed limits.

2. Achievable Energy Savings

Achievable energy savings and impacts were not calculated for this measure.

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[1] Cope, 1973

[2] French, 1974

[3] Ibid

FIGURE V-37

EFFECT OF REDUCING SPEEDS TO 55 MPH
(1972)

VEHICLE	VEHICLE MILES ABOVE 55 MPH 10^6 Miles	FUEL CONSUMED ABOVE 55 MPH 10^6 Gallons	FUEL CONSUMED AT 55 MPH RATE 10^6 Gallons	FUEL SAVINGS 10^6 Gallons	PERCENT OF TOTAL FUEL	TOTAL FUEL 10^6 Gallons
Passenger Car	[illegible]	22,755	19,765	2,990	10.2	29,192
Single Unit Truck	64,803	7,184	6,020	1,164	10.0	11,679
Combinations	15,051	4,335	3,192	1,143	17.3	6,619
Buses	1,047	464	258	206	37.1	556
ALL VEHICLES	402,317	34,708	29,205	5,503	11.5	48,047

55 MPH Rates:		
	Passenger Car	19.05 MPG
	Single Unit Truck	11.43 MPG
	Combinations	4.76 MPG
	Buses	7.54 MPG

Source: French, A. and Bishop, H., "Analysis of Fuel Savings Through Reduced Speed Limits", Federal Highway Administration, HHP-40, April 1974.

FIGURE V-38

FORECAST FUEL SAVINGS

$(10^{12}$ BTU)

VEHICLE	YEAR			
	1977	1980	1985	1990
Passenger Car	503	572	711	883
Single Unit Truck	197	225	279	346
Combinations	193	220	273	333
Buses	35	40	49	61
TOTAL	928	1,057	1,313	1,630

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VI. ENERGY CONSERVATION IN THE POWER GENERATION SECTOR

A. INTRODUCTION

The power generation sector and the five energy "conservation" measures analyzed therein are a somewhat unique portion of this study. The uniqueness originates in the fact that the measures are not limited to "conservation" in a narrow sense of avoiding the use of energy, but instead, the term is broadly defined to mean the conservation of exhaustible fuels. In this context, three types of measures can be defined. First, there is the conservation of energy through the more efficient use of existing non-replenishable fuels. Waste heat recovery from power plants using both fossil and nuclear fuels is one such measure considered in this study. However, measures such as higher efficiency boilers or better maintenance were not analyzed in depth because it was felt that the electric utilities have excellent records of performance in these areas at present.[1]

The second major category considered is the use of replenishable energy sources as substitutes for non-replenishable energy sources. In this study solid waste is the replenishable resource or from a solid waste management viewpoint, the unending problem. Three measures have been selected for in-depth analysis: (1) direct firing of solid waste, (2) the use of solid waste as a feedstock in the biological generation of methane, and (3) the pyrolytic treatment of solid waste to produce oil and gas, both of which can be used for power generation.

The third type of conservation category is the utilization of an "inexhaustible" source as a substitute for non-replenishable fuels. Solar, tidal, geothermal and wind energy are all candidate sources, each of which is currently being investigated in-depth by various research organizations. Wind energy as a "fuel" for power generation is the measure which has been examined in this study.

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[1] LeMay, 1974

Each of these measures is described and discussed below. Figure VI-1 provides summary definitions. Because of the significance of solid waste, a discussion of solid waste composition, economics and flows prefaces the discussion of measures.

FIGURE VI-1

ENERGY CONSERVATION MEASURES

POWER GENERATION SECTOR

SERIAL NO.	CONSERVATION MEASURE	IMPLEMENTATION STRATEGY
P-1	Direct firing of solid waste for power generation	state and federal subsidy for purchase and depreciation costs of plant equipment.
P-2	Pyrolysis of solid wastes for production of fuel	state and federal subsidy for purchase and depreciation costs of plant equipment
P-3	Bioconversion of solid wastes	state and federal subsidy for purchase and depreciation costs of plant equipment
P-4	Recovery of waste heat from power generation	federal and/or state subsidies
P-5	Use of wind energy as a supplement power source	program of federal grants to assist in research and development problem-solving combined with loan assistance and subsidies

B. POWER GENERATION BASELINE DATA AND SUMMARY OF SAVINGS

An important constraint in the estimation of power generation with solid waste as a fuel is the stock of power plant boilers and the anticipated additions to that stock. Direct firing of solid waste can be most rapidly implemented in generating plants which are currently burning coal as fuel. In 1972 thermal generation was estimated at 1.47×10^{12} Kwh. Using a national average heat rate of 10,479 BTU/Kwh, this demand would require a thermal input of approximately 15.4×10^{15} BTU, consisting of: coal (52.3%), oil (18.5%), gas (25.5%) and nuclear (3.7%).[1]

The above data reflects the existing electrical power generation stock. The above fractions are not fixed for the future for many power plants can burn two or three different fuels, and the actual fuel used is determined by current prices. However, as this data will be used in the subsequent section, it is adequate.

Figure VI-2 provides estimates of fuel distribution to 1990, as derived from data provided by A.G.A. staff.[2]

Five energy conservation measures for the power generation sector were analyzed in detail. These measures span the spectrum of conservation from the more efficient use of fossil fuels to the substitution of "inexhaustible" sources of energy for non-replenishable resources. Significant savings are possible with the use of each measure, however, only the direct firing of solid waste as a fuel in boilers provides a short term payoff under current technological and economic conditions. Firing of solid waste also relieves a solid waste management problem and this accounts for its comparatively high stage of development with large scale projects operational. Wind energy, although proven in small scale applications, provides the greatest overall potential in that this source is "inexhaustible". However, large scale applications are still some time off and commercial applications won't be of any significance until 1990.

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[1] EEI, 1973.

[2] AGA, 1974.

The potential savings from each measure are summarized in Figure VI-3 . However, in no case are these savings additive, and in some cases they are competitive. For example, if significant quantities of electricity are generated from wind systems, the recoverable waste heat will decrease. In contrast, utilization of solid waste as a fuel will have little effect on recoverable waste heat.

Measure two, pyrolysis of solid waste can result in gas and/or oil production. Figure VI-3 presents estimates of energy savings, assuming 100% conversion to oil or gas. Savings resulting from any mix of these two can be readily estimated as proportions of the 100% estimate.

FIGURE VI-2

TOTAL ELECTRICITY GENERATED FROM VARIOUS FUELS (10^{12} BTU$_e$)					
YEAR	NUCLEAR	HYDRO	FOSSIL FUEL	TOTAL	FOSSIL FUEL AS PER CENT OF TOTAL
1977	2070	834	6508	9412	69
1980	3256	869	7190	11320	64
1985	6865	877	7787	15530	50
1990	11300	880	7897	20080	39

FOSSIL FUEL REQUIREMENTS POWER GENERATION (10^{12} BTU$_t$)				
YEAR	GAS	OIL	COAL	FOSSIL FUEL TOTAL
1977	6872	715	12275	19860
1980	7909	566	13467	21940
1985	8706	364	14704	23770
1990	9775	92	14370	24240

Source: MATHEMATICA estimates based on the Federal Energy Administration's Project Independence and data provided by American Gas Association staff.

FIGURE VI-3

SUMMARY OF ENERGY SAVINGS - POWER GENERATION SECTOR

(Trillions of BTUs)

MEASURE	Maximum Energy Savings				Achievable Energy Savings			
	1977	1980	1985	1990	1977	1980	1985	1990
Direct Firing of Solid Waste	54	97	447	759	54	97	447	759
Pyrolysis of Solid Waste	0	3	25	80	0	3	24	80
Bioconversion of Solid Waste	0	3	18	58	0	3	18	58
Waste Heat Recovery	0	1431	4496	7451	0	1431	4496	7451
Wind Energy	0	1	31	137	0	1	31	137

C. SOLID WASTE

1. Why Energy Recovery

In its 1974 Report to Congress, EPA's Office of Solid Waste Management Programs reported the following data for 1971:

- Total municipal waste generated was estimated to be 125 million tons, of which 80% was organic:
- 80% of raw urban refuse was combustible;
- The heat value of raw urban refuse was 4,600 BTU/pound or 9,200 MBTU/ton.*
- Average cost of solid waste collection was $18/ton; and
- Average cost of solid waste disposal was $4/ton for a total collection and disposal cost of $22/ton.

Using the above information, the cost of waste management was computed to be .24¢/MBTU. Each pound of solid waste, with an energy content of 4,600 BTU, costs 1.1¢ to collect and process. That is, .24¢ is spent to collect and "throw away" 1,000 BTU. As a reference point, based on data in Gas Facts 1972, the average industrial price for natural gas was computed to be .43¢/MCF or .043¢/MBTU. On a per BTU basis, it costs five times as much to dispose of solid wastes as to purchase natural gas! The average price of No.2 fuel oil in 1972 as computed from data reported in Platts Oilgram Price Service was 12.2¢/gallon or .087¢/MBTU. Each ton of solid waste contains the BTU equivalent of 58 gallons (approximately 1.4 barrels) of oil, which cost over $7 in 1972. $22 is spent to throw away the energy content of 1.4 barrels of No.2 fuel oil costing $7.

In light of rapidly increasing fossil fuel costs, the practice of spending .24¢ to "throw away" one thousand BTU is somewhat questionable. Therefore, this study has considered the recovery of energy from solid waste in depth.

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*MBTU is defined as 1000 BTU. MMBTU is 1,000,000 BTU.

2. Solid Waste Resources

It has been estimated that the U.S. generates in excess of three billion tons of waste per year[1] of which agricultural wastes amount to 2.5 billion tons. Two billion tons of these agricultural wastes are manure.[2] If it were possible to extract the entire energy content of the total U.S. waste (3 billion tons @ 9.2 million BTU/ton of raw refuse), this would produce 27.6×10^{15} BTU_e or 150% of the annual U.S. electric energy demand in 1972.[3] If this anaysis could be believed, then the U.S. could satisfy all domestic electric energy demands through the simple expedient of converting all solid wastes directly to energy. There are several reasons why this is an unrealistic estimate, and the following discussion will develop a more reasonable estimate of the energy potential of solid waste.

The basic approach used to estimate the quantity of solid waste available for energy conversion is to look at both the origins of solid waste and the processes which can be utilized to extract energy from this waste in order to identify factors which will reduce the absolute potential.

As pointed out above, the bulk of the solid waste generated is from agricultural processes and is located at some distance from the energy consuming urban areas. Animal manure is treated and effluents are discharged into streams; while solid waste originating from crop production is often left to decompose in fields.

The Bureau of Mines[4] has estimated that urban waste, including domestic, municipal, industrial and commercial refuse amounts to only 400 million tons per year. While this quantity of urban refuse is comparatively small, it does have the advantage of being available in those places where energy is required. If its entire energy content could be extracted, this quantity of urban refuse would equal almost 2.9 x 10^{15} BTU[1] or one-fifth of the U.S. annual electric demand.

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[1] Hammond, *et al*, 1973.

[2] Vaughn, 1973.

[3] AGA, 1974.

[4] Appell, *et al*, 1971.

While there is some research ongoing into the use of agricultural waste for energy generation, most notably at the University of Pennsylvania's Center for Energy Management, the bulk of the research has focused on the conversion of urban waste. Some studies point out that the use of agricultural waste including the cultivation of specially grown "high energy" crops e.g. fast growing algae strains, for direct conversion to thermal energy or for conversion to oil or gas is at least 25 years away from large scale production.[2,3]

In this study, urban refuse was selected as the most promising potential source of replenishable energy in the near term. As pointed out by Lowe (1974) about 70% to 80% of residential and commercial waste is generated in the larger metropolitan areas, where it is most easily collected and where the energy demands and markets are greatest.

Most studies,[4,5,6] report that energy recovery systems require large quantities of wastes delivered to a single site in order to achieve necessary economies of scale. Estimates of minimum size range from 100 to 250 tons per day. This large amount is required so that economies of scale at disposal can compensate for high collection costs. At an estimated 5 lb. per capita per day waste generation rate, this would represent waste from 40-100,000 persons.

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[1] Assuming 80% combustible and 9.2MMBTU/ton.

[2] Hammond, et al, 1973.

[3] EPA, 1974.

[4] Hammond, et al, 1973.

[5] AGA, 1974.

[6] Lowe, 1974.

One notable exception to the above approach is the concept of the Integrated Utility System as being developed by the Department of Housing and Urban Development[1]. HUD's approach is to process solid waste on-site, recovering thermal energy for use in either on-site sewage sludge disposal, or as an auxiliary fuel for hot water heating. The approach that HUD has taken eliminates the high collection costs, and, therefore, the need for large quantities of energy to justify any additional heat recovery equipment. However, the small scale approach is not feasible in the power generation sector.

In conclusion, then, only urban refuse will be considered as feasible for use for power generation with the period extending to 1990.

3. Quantity and Quality of Urban Refuse

In 1968, a survey was conducted in which municipalities were asked to estimate the quantity of urban refuse collected. This national survey resulted in a widely accepted estimate of 5.3 lbs per day per capita waste, for a total of 190 million tons of urban refuse in 1967.[2] Because there was considerable concern as to the validity of this estimate, the EPA Office of Solid Waste Management Programs prepared a revised estimate of per capita waste generation based on an analysis of material flows. This new estimate, 3.32 lbs/capita/day is the most current "best" estimate of urban refuse generation rates, and results in approximately 125 million tons of urban refuse for 1972[3].

Even this somewhat smaller estimate would result in 1.15×10^{15} BTU if 100% was converted to energy. However, as pointed out in another study,[4] only the larger densely populated areas can provide waste in sufficient quantities within reasonable collection areas as required to support a large waste disposal operation. If only SMSA's are considered, then only 92.4 million tons of urban refuse are available.

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[1] HUD, 1972.

[2] Black, et al, 1968.

[3] Smith, 1974.

[4] Lowe, 1974.

Thus the maximum energy available from urban solid waste is estimated at 850 x 10^{12} BTU. (It should be pointed out that Lowe estimates 832 x 10^{12} BTU based on 4,500 BTU/lb.)

The energy available from urban solid waste is determined by three factors; (1) the urban population, (2) the refuse generated per capita, and (3) the BTU content of that refuse. Each of these is examined in detail to develop forecasts of energy availability.

Urban Population

1970 Series E projections as prepared by the Bureau of Census project a growth rate of 9.3% for the ten year period 1970 to 1980 or a rate of less than 0.9% per year. This series is the basis of solid waste projection as used by EPA,[1] although the MRI report[2] uses series D which is somewhat higher. In light of current trends, the lower rate of Series E is more appropriate. Projections are shown in Figure VI-4.

Census estimates the 1971 U.S. population to be 206.2 million. Approximately 73.5% of this population was found in urban areas[3]. In their projections[4,5] EPA uses population within SMSA's as an estimate of total population available to support energy recovery programs and on this basis Levy[6] estimates that 75% of the U.S. population is accessible to central processing plants.

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[1] Lowe, 1974.

[2] MRI, 1974.

[3] Dept. of Commerce, 1973-A.

[4] Lowe, 1974.

[5] Levy, 1974-A.

[6] Ibid.

Changes in the national trend toward increasing urbanization over the last three decades significantly affects this fraction. 64% and 69% of the U.S. population was located in urban areas for 1950 and 1960 respectively. A continuation of this trend would result in 78.6% and 84.0% of population in urban areas in 1980 and 1990 respectively.[1]

Considering these trends both in population growth and in the fraction of the population found in urban areas, Figure VI-4 provides estimates of the maximum population available to support solid waste energy recovery projects.

Per Capita Refuse Generation

The second factor to be considered is the quantity of refuse generated for municipal collection. The current baseline estimate being used by EPA is 3.32 pounds per capita per day. Lowe[2] projects the per capita rate to increase by 2% annually resulting in an average of 3.91 pounds per person per day for 1980. Other estimates[3] based on projections prepared in 1971 indicate a compound growth rate of 1.5% per year. Conservatively assuming a 1.6% annual growth rate daily per capita solid waste generation rates for 1977 are shown in Figure VI-5. Lowe[4] also assumes that the average person in an SMSA generates more waste (3.60 pounds per capita per day) than does his rural counterpart. However, without substantiating studies, a more conservative estimate was used.

---

[1] MATHEMATICA estimate.

[2] Lowe, 1974.

[3] Envirogenics, 1971.

[4] Lowe, 1974.

FIGURE VI-4

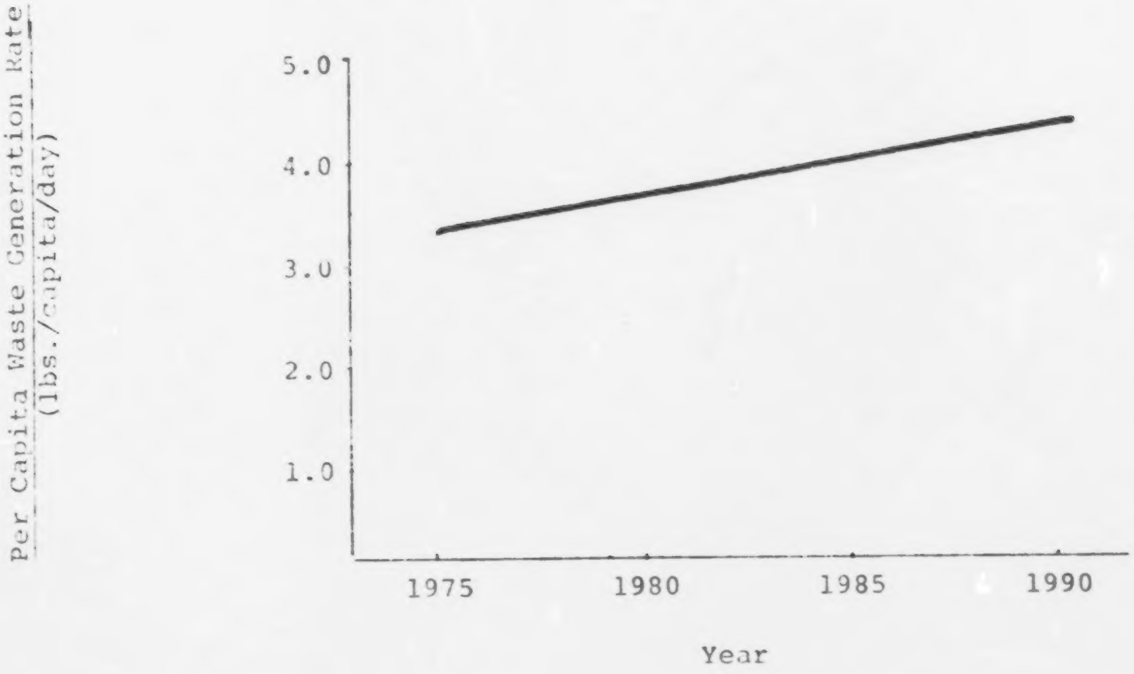
MAXIMUM POPULATION AVAILABLE TO SUPPORT SOLID WASTE ENERGY RECOVERY PROJECTS

YEAR	POPULATION[1] (Millions)	FRACTION OF[2] POPULATION IN URBAN CENTER (Per Cent)	AVAILABLE POPULATION (Millions)
1977	219.7	77.1	169.
1980	226.9	78.6	178.
1985	239.3	81.2	194.
1990	250.6	84.0	210.

Sources: 1. Population: U.S. Census Projections
2. Fraction of Population in Urban Centers: MATHEMATICA, Inc.

FIGURE VI-5

Per Capita Waste vs. Time



Source: MATHEMATICA, Inc. estimates based on Lowe, 1974 and Environgenics, 1971.

BTU Content of Urban Waste

The current estimate of the BTU content of raw urban refuse is 4600 BTU per pound[1] which is in reasonable agreement with some earlier estimates of 5,000 BTU/pound[2]. Various estimates range from 3,000 to 8,000 BTU per pound[3].

It is also anticipated that due to packaging changes, standard of living changes and other technological changes, the average BTU content will increase in the future. One published estimate for the rate of increase is 0.9% per year[4] which is used for this study. Heating values of solid waste over the time periods of this study are shown in Figure VI-6.

4. Summary

Considering the three factors reviewed above, estimates of the total energy available from urban solid waste in the period to 1990 were computed and are reported in Figure VI-7. These are estimates of the maximum quantities of solid waste which could be processed for energy recovery through 1990. In order to estimate maximum energy recovery, process efficiencies for energy recovery systems will be applied to the maximum energy available. Projections over time are based on commercialization or the technological implementation trend developed in the analysis of direct firing of solid wastes for energy recovery.

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[1] EPA, 1974.

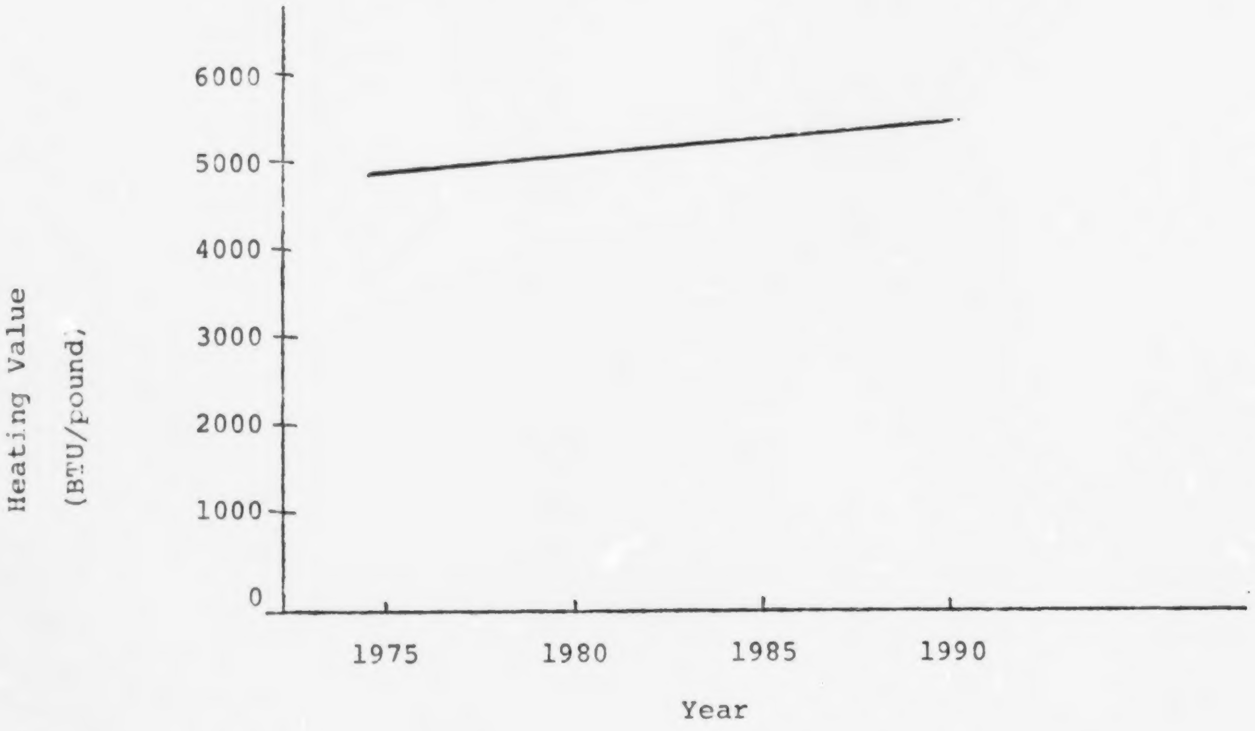
[2] Envirogenics, 1971.

[3] Hammond, et al, 1973.

[4] Ibid.

Figure VI- 6

HEATING VALUE OF SOLID WASTE vs. TIME



Source: MATHEMATICA, Inc. estimates based on EPA, 1974, Environgenics, 1971, and Hammond, et al, 1973.

FIGURE VI-7

MAXIMUM SOLID WASTE POTENTIAL ENERGY

YEAR	POPULATION AVAILABLE (Millions)	PER CAPITA RATE (pound/day)	HEATING VALUE (BTU/pound)	MAXIMUM AVAILABLE ENERGY (10^{12} BTU/year)
1977	169.	3.67	4860	1,110
1980	178.	3.83	4990	1,240
1985	194.	4.14	5215	1,530
1990	210.	4.48	5454	1,870

Source: MATHEMATICA, Inc. estimates

D. DIRECT COMBUSTION OF SOLID WASTE

1. Maximum Energy Savings

The direct combustion of solid waste to produce either thermal or electric power is the least complex mechanism for recovery of solid waste energy in the power generation sector. Solid waste can be mixed with other boiler fuels such as coal, or can be utilized as a single fuel in power plants. When solid wastes are used directly as a fuel, they are frequently mixed with coal in order to decrease instantaneous variations in the BTU content of the boiler fuel resulting from heterogenieties in the waste stream.

The use of solid waste as a boiler fuel was analyzed in depth by Envirogenics, under contract to EPA[1]. Engineering designs and cost estimates were prepared and performance characteristics were estimated. Both new plant boilers and retrofit operations were considered, and operations were constrained to a fuel which had a maximum solid waste content of 60%. Power plants in the range of 100 to 500 MW were analyzed, with the range of boilers scaled down so as to power a 50 MW generator. This study established the engineering feasibility of solid waste as a supplemental fuel and pointed out how, due to its generally low sulfur content, solid wastes would reduce sulfur oxide emissions.

There are two basic studies which provide estimates of the potential for solid wastes as a fuel in power generation. The approaches taken are markedly different, but are in good agreement.

The first study prepared by EPA staff[2] estimates potential energy recovery for the year 1980. The basic approach was to identify and enumerate all municipalities which are considering energy recovery projects and to determine whether such operations can be in place by 1980.

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[1] Envirogenics, 1973.

[2] Lowe, 1974.

Based on this pragmatic approach, EPA estimated that 33,600 tons/day of solid waste will be used either as boiler fuel or incinerated in waterwall incinerators. Of this total 25,500 tons/day were committed to power generation, 4600 tons/day to process uses or heating and cooling, and 3500 tons/day were not allocated. It is assumed that this last 3500 tons/day will be allocated in the same proportions as the existing commitments, resulting in a total estimate of 28,500 tons/day of solid waste in power generation. At 4600 BTU per pound, this allocation amounts to 95.7 x 10^{12} BTU or 7.8% of the total solid waste potential for 1980 (Figure VI-7). It is felt that in the absence of additional major stimulation or restraints, the above "goal" is likely to be met.

The second approach, employed by MRI under contract to EPA[1] projects energy recovery as a function of the costs of land required for sanitary landfills and the value of energy. The basic hypothesis was that as disposal costs increase due to increasing land costs, and as the energy content of solid waste increases in value due to increases in fuel costs, there will be an increase in the degree of incineration to reduce land fill volume and energy recovery to reduce total costs. A computational algorithm was developed to expedite calculations and resource recovery potential was computed on a state by state basis. Disaggregation of analysis to the state and SMSA is the strength of this method; however, major shortcomings include the questionable validity of both the basic hypothesis and the energy price forecasts.

Based on MRI estimates, energy recovery in 1980 will be 61.4 x 10^{12} BTU or 5% of the potential, and in 1990 recovery will be 486 x 10^{12} BTU or 26% of the maximum potential (Figure VI-8). MRI estimates tons per day of solid waste processed for recovery, and actual MRI energy projections are slightly lower than the above due to differences in higher heat values of refuse. All energy recovery is assumed to be through direct firing and does not explicitly exclude the use of recovered energy in industrial, residential or commercial sectors.

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[1] MRI, 1974.

MRI estimated energy costs are derived from National Coal Association data and is shown in Figure VI-8. The high and low state averages are shown. In comparison, prices for energy for the electric utility industry as developed by A.G.A.[1] are also shown. The price is computed as an average of all fuels weighted by fuel use. (Prices shown do not reflect recent increases in oil prices.) As can be seen, the MRI prices are consistently lower than A.G.A/MATHEMATICA estimates, tending to produce under estimates of the amount of recovered energy. The use of more realistic energy values could reconcile the difference between EPA and MRI estimates for 1980 recovery.

While it is impossible to recompute the MRI estimates within the scope of this study, it can be assumed that the general implementation trends hold. Normalizing this trend to the pragmatic EPA estimate for 1980, MATHEMATICA has projected energy recovery from solid waste by direct firing in the power generation sector (Figure VI-9).

It was assumed that coal would be displaced by solid waste, and for 1990, coal demand would be decreased by 5.3% through direct firing of solid wastes.

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[1] AGA, 1974.

FIGURE VI-8

ENERGY PRICE FORECASTS

(¢/MILLION BTU)

YEAR	MRI [2]		AGA/MATHEMATICA[1]	
	HIGH	LOW	HIGH	LOW
1980	51.3	19.9	130	38.1
1985	61.8	24.0	178	50.0
1990	72.4	28.2	300	65.0

[1] Source: MATHEMATICA estimates based on data provided by A.G.A. staff.

[2] MRI, 1974.

FIGURE VI-9

ANTICIPATED ENERGY SAVING

POWER GENERATION SECTOR

DIRECT FIRING OF SOLID WASTE

YEAR	TOTAL POTENTIAL ENERGY (10^{12} BTU)	PERCENT OF ENERGY RECOVERED (MATHEMATICA)	ENERGY RECOVERED (10^{12} BTU)	ESTIMATED COAL REQUIRED FOR POWER GENERATION (10^{12} BTU)	COAL DISPLACED (Per Cent)
1977	1,110	4.9	54.4	12275	0.4
1980	1,240	7.8	96.7	13467	0.7
1985	1,530	29.2	447.0	14704	3.0
1990	1,870	40.6	759.0	14370	5.3

Source: MATHEMATICA, Inc.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

PMM&Co. used, for impact analysis, MATHEMATICA's estimate of the feasibility of energy savings (described in the previous section) due to direct firing of solid waste to produce steam to run turbines for generating electricity. Therefore, given a 100 percent implementation rate, the total cumulative energy savings between 1977 and 1990 would be 4602 Trillion BTUs.

In summary, the estimates took the following factors into account:

- the engineering feasibility of using solid waste as a supplemental fuel for both retrofit and new power plants
- general present and projected economic incentives for more direct combustion of solid waste, e.g., rising costs of land for landfill and the increasing value of solid waste energy content.

There are many instances where systems for direct firing of solid waste to generate power are currently in use. In Europe, the use of solid waste as a fuel is common. Germany has more than 20 refuse burning installations equipped with steam heat recovery systems. In this country, a public corporation in Nashville, Tennessee, is using solid waste to produce steam for heating and for driving the turbines that power large water chillers. The steam and chilled water will then be piped to downtown Nashville.

A private engineering firm, Horner and Shiplin, has carried out a project to use certain types of refuse from the city of St. Louis to replace 10 to 20 percent of coal burned at an electric company.[1]

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[1] Kasper, 1973.

The maximum energy savings potential did not take into account the effect of the implementation strategy upon the maximum possible energy savings. State or federal grants for the purchase of new equipment would probably increase the reate at which installations adapt their equipment to increase combustion of solid waste. There were no concrete data to quantify the impact of such incentives on the level of implementation.

IMPACTS

A summary of impacts is shown in Figure VI-10.

Private Consumer

Direct consumer impact is uncertain; however, if it is assumed that direct operating savings would be passed on to consumers, and that approximately 20 percent of consumption is residential, total consumer savings would be $1.7 billion.

Public Sector

Solid waste disposal costs, primarily local government costs for landfill and other disposal processes, could be reduced. However, such costs were not estimated within this analysis. Finally, since primary fuel is domestic coal, no balance of payment change was estimated.

Quality of Life

Quality of life impacts should be nonexistent for implementation of this measure, since it deals only with the tehcnological problem of producing power through an alternate means, rather than a reduction of power.

Scarce Materials/Resources

Using sold waste for fuel in power generation will serve to take advantage of the heat content of materials which otherwise might be discarded. It will also aid in the conservation of coal and other fuels used for power generation.

FIGURE VI-10
DIRECT FIRING IMPACT SUMMARY

	Annual Impact 1977	1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	54.4	96.7	447	759	4,602
2. Estimated Feasible	54.4	96.7	447	759	4,602
B. Impacts (Millions of Dollars)					
1. Private Industry					
Electric Industry	$92m	$162m	$751m	$1,276m	$8,405m
2. Private Consumer					
Savings	$18.9m	$32.2m	$150m	$255m	$1,681m
3. Public Sector					
Government		NOT ESTIMATED			
Balance of Payments		NOT APPLICABLE			
4. Employment (Jobs)		INSUFFICIENT DATA			
5. Environment (Percent Reduction)					
Particulate Emissions		Increase - Not Estimated			
Solid Waste Reduction	2.1%	3.8%	17.4%	30.0%	

Because of the relative greater corrosive nature of combusted solid waste, some problems could occur in providing adequate corrosion-resistant materials for solid waste fixed facilities. These problems, however, should not be major.

Environment

The combustion of solid waste for electric power production has important environmental impacts in the air pollution and solid waste areas. Thermal pollution is not affected, since the measure entails substitution of one energy source for another.

A recent report[1] on the test project in St. Louis indicates that solid waste combustion in power plants may actually increase air pollutants. It notes that particulate emissions from a solid waste-fired boiler increased so substantially as to overload the pollution abatement apparatus on the installation. Contrary to expectations, SO_2 emissions were not noticeably decreased.

It is likely that better design will eliminate these negative environmental impacts of solid waste combustion; nevertheless, they appear to be stumbling blocks at the moment.

Combustion of solid waste can have an extremely positive effect on reduction of solid waste pollution. By 1977, 6.45 million tons of solid waste, or about 3.2 percent of the solid waste stream, can be eliminated through this measure, with an associated reduction in landfill demand of 25.8 million cubic yards. By 1990, fully 70 million tons, or 30 percent of the solid waste stream can be reduced through solid waste combustion, with an associated landfill demand reduction of approximately 361 million cubic yards.

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[1] EPA, 1974B.

Private Industry

This measure assumes that the direct firing of municipal waste will displace coal consumption only. Between 1977 and 1990, the total coal tonnage displaced is estimated at 186 million tons at a value of $10.9 billion.[1] Assuming constant coal prices, utilities' use of the waste for direct firing would decrease coal consumption by $10.9 billion, but their operating savings would be somewhat offset by the capital and operating costs of equipment for processing the waste before combustion. Based upon MRI research, the estimated average annual operating and capital costs for a 300,000 ton/year plant would be $1.7 million.[2] The estimated added operating and annual capital cost, using available waste for direct firing, would be approximately $2.6 billion. The net savings in electric power production between 1977 and 1990 are estimated at $8.4 billion.

Employment

Assuming that no material change will occur to the electric facility manpower requirements using direct firing, the only employment impact might be increased employment in collecting and processing the solid waste. Data did not permit computation of employment impacts due to this measure.

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[1] Using East Coast price of industrial stoker coal, September 1974.

[2] MRI, 1972.

E. PYROLYSIS OF SOLID WASTES

1. Maximum Energy Savings

The second energy conservation measure considered, pyrolysis, results in the production of a fuel - either liquid or gaseous, which can be burned in boilers to raise steam or in turbines. Pyrolysis is the thermal decomposition of materials in an atmosphere deficient of oxygen. A description of the processes available is found in an article by Levy;[1] however, pyrolysis results in three products: (1) a gas consisting of various fractions of hydrogen, methane and carbon monoxide; (2) an oil that contains acids, methanol and acetone; and (3) a char consisting of carbon, glass, metal and rock. The concept is a proven one. However, the reliability and economics of pyrolysis are yet to be established. Several current technology demonstrations are expected to provide needed data.

There has been considerable research into pyrolysis and some of the available information is reported below. San Diego, California[2] will use solid waste to generate a liquid fuel with a heating value of 94,000 BTU per gallon and will displace No. 6 fuel oil (145,000 BTU/gal). The fuel is produced at a rate of one barrel (3.95×10^6 BTU) per ton of solid waste (9.2×10^6 BTU). The wastes are preprocessed, removing non-combustibles. The process has an efficiency of about 43%. Efficiency is defined as energy content of the resulting fuel over the energy content of the solid waste feedstock.

Linde is currently constructing a 200 ton per day test facility in West Virginia. Gas, with an energy value of 300 BTU per cubic foot will be produced. Because of the low BTU content in comparison with natural gas, this gas is expensive to transport and store and plans are to utilize it in the vicinity of the pyrolysis plant. Linde estimates that a gas yield of 7×10^6 BTU per ton of solid waste can be obtained for an efficiency of 76%.[1]

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[1] Levy, 1974 A.

[2] Ibid.

Monsanto is currently constructing a 1000 ton per day plant in Baltimore.[2] This plant produces a gas with a heat content of approximately 100 BTU per cubic foot, which is immediately combusted on site to generate steam at a rate of 200,000 pounds per hour. Number 2 heating oil at the rate of 7.9 gallons per ton of solid wastes is also required.

There are several other studies and demonstration projects currently underway. The most notable of these is the Bureau of Mines program to produce an oil equivalent.[3] Bureau of Mines reports that 1.25 net barrels of oil could be produced per ton of dry organic material processed. The report does specify that the energy content is 15,000 BTU/lb., but does not specify the oil density. No. 6 oil has a density of 8.18 lb/gal., while one pyrolytic oil has a density of 10.8 lbs/gal.[4] Assuming 10 lbs/gal., then the Bureau of Mines oil has a BTU value of 7.88×10^6 BTU per ton of dry organic urban waste. However, the Bureau of Mines estimates dry organic wastes to be only 50% of total urban refuse and applying a 50% correction to the above estimate of system output results in a yield of 3.94×10^6 BTU per ton of raw urban refuse or an efficiency of 43%. Bureau of Mines estimates that as an alternative to oil production, pipeline quality gas could be produced at a rate of 5.0 cubic feet per pound of dry, metal and glass-free urban refuse.

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[1] Levy, 1974, B.

[2] Ibid.

[3] Anderson, 1972.

[4] Levy, 1974, B.

Most published studies do not provide all the data necessary to compute process efficiencies and if efficiencies are required, several assumptions are usually required. However, from the above data, oil pyrolysis has an apparent efficiency of 43%, while gas pyrolysis output varies from 54% to 76%. A conservative estimate for purposes of this study is an efficiency of 55% for gas producing systems.

Few commercial pyrolytic projects are operational and EPA estimates that the capability to process 1700 tons per day will be in place by 1980. Two hundred tons per day will be producing oil, while 1500 tons per day will produce gas. These projects will generate 289 x 10^9 BTU of oil from 672 x 10^9 BTU input and 2770 x 10^9 BTU of gas from 5040 x 10^9 BTU input. In total, 3.06 x 10^9 BTU per year of oil and gas are produced. Solid waste required is 5.71 x 10^{12} BTU or 0.5% of the 1240 x 10^{12} BTU available (Figure VI-7).

Assuming the same implementation rate for pyrolysis as was used for direct firing, but with a ten year delay to compensate for the lack of proven large scale projects, estimates of energy available by pyrolysis of solid waste are shown in Figure VI-11. These quantities of equivalent oil and gas are negligible in comparison to projected oil and gas demands for power generation.

FIGURE VI-11

ENERGY SAVINGS, PYROLYSIS OF SOLID WASTES FOR CONVERSION TO POWER GENERATION FUELS

YEAR	SOLID WASTE POTENTIAL (10^{12} BTU)	PER CENT* OF WASTES PYROLIZED	ENERGY CONTENT OF SOLID WASTE PYROLYZED (10^{12} BTU)	OIL PRODUCED (10^{12} BTU)	GAS PRODUCED (10^{12} BTU)
1977	1110	Negligible	-	-	-
1980	1240	.5	6.2	2.7	3.4
1985	1530	3.0	45.9	19.7	25.2
1990	1870	7.8	146	62.8	80.3

Source: MATHEMATICA, Inc.

[*] Implementation schedule assumes same implementation pattern as was used for direct firing, however with 10 year lag.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

The implementation strategy for this measure was to be federal and/or state tax credits and favorable depreciation rates for capital investment in pyrolysis equipment. Any impact such economic incentives would have on the rate of implementation would be positive. There were no data, however, to quantify an increase in the implementation rate above estimates of maximum potential energy savings.

As discussed under the direct combustion measure, there are precedents for giving tax credits for certain types of capital equipment investment (e.g. the IRS 7 percent tax credit). After the appropriate percentages of credit and depreciation rate have been determined, the relevant tax agencies would have to set up the usual safeguards against abuses.

IMPACTS[1]

A summary of impacts is shown in Figure VI-12.

Private Consumer

The maximum potential consumer impact could be an added cost of $1.84 per 1000 cubic feet.[2] However, since the gas supply would be a mixture of natural and pyrolysis supplied gas and since pyrolysis gas would be a small proportion of the total, the maximum impact would be diluted to only a minor impact. Simplistically, the imapct could be estimated at $122 million[3]

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[1] Impacts assume gas production only.

[2] However, there would be a small increase over the cost of supplemental gas from LNG, coal or other similar sources.

[3] Assumes 1,031 BTUs per cubic foot.

FIGURE VI-12
PYROLYSIS IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. **Energy Savings** (BTUs x 10^{12})					
1. Maximum	0	3.4	25	80	340
2. Estimated Feasible	0	3.4	25	80	340
B. **Impacts** (Millions of Dollars)					
1. **Private Industry**					
Gas Production					
Added Annual Operating/ Capital Cost	0	($6.1m)	($45m)	($143m)	($610m)
2. **Private Consumer**					
Cost		($1.2m)	($9m)	($29m)	($122m)
3. Public Sector					
Government	0	($2.5m)	($12m)	($31m)	($46m)
Balance of Payments		$ .02m	$.14m	$.45m	$1.9m
4. Employment (Jobs)			Insufficient Data		
5. Environment (Percent Reduction)					
Solid Waste		.16%	1.1%	1.3%	

between 1980 and 1990, assuming that 20 percent of gas consumption would go to residential use.

Public Sector

At present, only 1.4 percent of natural gas is imported. As a result, the reduction in imports would be quite small. Assuming a constant import rate over time, 1.9 million dollars in natural gas imports could be avoided by 1990.

Since it is quite clear that at a minimum a 7 percent investment tax credit would be required to develop this measure, the state and/or Federal government would stand to lose an estimated $46.0 million in future tax revenues. This is only a partial estimate and does not take into account depreciation allowance.

Quality of Life

Quality of life impacts should be nonexistent for implementation of the pyrolysis measure, since it deals only with a technological problem of producing power through an alternate means, rather than a reduction of power.

Scarce Materials/Resources

Thermal/chemical treatment such as pyrolysis can supply oil or gas, and hence help conserve these two valuable energy sources. By pyrolyzing waste material, it is possible to take advantage of its energy content which otherwise might be lost.

In addition, significant quantities of char and oil can be produced through thermal/mechanical treatment of wastes; char itself is a valuable energy source when compressed into briquets.

The corrosive nature of thermal/mechanical processes will increase the demand for corrosion-resistant materials, but this should not constitute a major problem.

Environment

Pyrolysis can produce clean methane through a low pollution process. This methane could be used to supplement fossil fuel power plants to reduce air pollution from the plants. Monsanto Corporation has been experimenting in Baltimore using a 70% coal-30% pyrolysis-produced gas mix in a conventional boiler. Preliminary results[1] show that sulfurdioxide (SO_2), for example, is reduced, though not by as much as 30 percent.

On the assumption that SO_2 can be reduced by the proportion of pyrolysis-produced methane used, this measure could reduce SO_2 emissions by 3.86 million pounds in 1980 (.0105 percent of SO_2 emissions from electric power generation and .0067 percent of all SO_2 emissions), 26.4 million pounds in 1985 (.059% and .034%) and 78.4 million pounds in 1990 (.162% and .89%). As in the bioconversion measure, these air pollution reduction impacts are small.

Solid waste impacts of pyrolysis are more significant. In 1980, .34 million tons of organic solid waste could be removed from the solid waste stream (allowing for a 10% residue of char remaining from the pyrolysis process) which is about .16% of the projected solid waste stream. This means a reduced landfill demand of 3.98 million cubic yards. By 1985, these figures would rise to 2.5 million tone (or 1.1%) removed from the solid waste stream and a reduced landfill demand of 9.9 million cubic yards. By 1990, the measure could account for a reduction of 3.54 million tons (1.34%) from the solid waste stream, and a reduced landfill demand of 13.0 million cubic yards.

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[1] Private communication, Envirochem Division, Monsanto Corporation.

Private Industry

The pyrolysis gas produced from solid waste would replace natural gas consumption by a variety of energy users. In view of the current shortage of natural gas, no decreased production or sales in the natural gas industry is foreseen. The amount of generated gas by 1990 would be valued at $134 million based on current natural gas prices. Thus, gas utilities using the pyrolyzed gas in lieu of natural gas would realize $134 million in added sales during the study period. However, the savings would be offset by the capital and operating costs of new facilities to pyrolyze the waste. MRI has estimated the total annual cost to be $3.3 million for a 300,000 ton/year plant.[1] At this rate, the operating savings of $134 million would be offset by a cumulative net annual cost of $744 million, despite the possibility of a 7 percent investment tax credit. A net increase in production costs of $610 million would result to the gas utility companies.

The assumption that approximately 4,893 cubic feet of gas can be produced from one ton of solid waste would result in an approximate cost of $2.25 per 1000 cubic feet. At the present time, 1000 cubic feet can be purchased wholesale for $0.41.[2] This suggests that extensive pyrolysis processing is not likely to occur until natural gas wholesale prices increase drastically, processing costs are substantially reduced, and/or natural supplies can no longer meet demand. All of these occurrences appear likely in view of the current energy supply situation.

An unestimated added benefit would be the sale of char, a side product of some value when compressed into briquets.

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[1] MRI, 1972.

[2] *Technology Review*, 1974.

Employment

While the introduction of a new process would probably stimulate employment, insufficient data were available for impact estimation.

F. BIOCONVERSION OF SOLID WASTES

1. Maximum Energy Savings

The third method considered for recovery of energy from solid waste is bioconversion or anerobic digestion. Anerobic digestion of municipal sewage has been a common practice for many years. These same processes occur with solid waste as a feedstock and result in the production of methane and carbon dioxide. As reported by Levy[1], methane generated naturally in landfills is being recovered in both Los Angeles and Phoenix. However, the measure considered here is the operation of solid waste digesters for the explicit generation of methane by anerobic digestion.

NSF is currently investigating the potential for methane generation[2]. DynaTech estimates that at a scale of 1000 tons per day, only 300 tons per day will be converted to methane at a ratio of 12,000 cubic feet methane per ton. This data results in an efficiency of 39% or 3.6×10^6 BTU of gas per ton raw urban refuse input.

In another study,[3] it was reported that methane production for two different refuse samples was 5.22 and 4.35 scf per pound of preprocessed material added for an an efficiency of about 40%.

Unfortunately, there is little commercial experience with anerobic generation in the United States and estimates of widespread commercialization are indeed difficult to generate. One estimate is that one billion cubic feet of gas from either pyrolysis or anerobic digestion is possible by 1980.[4]

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[1] Levy, 1974 B.

[2] DynaTech, 1974, A & B.

[3] Pfiffer & Liebman, 1974.

[4] FPC, 1974.

Anerobic digestion results in gas production and can be used as a substitute fuel. Assuming the development of bioconversion processes can parallel the development of pyrolytic processes, the estimates in Figure VI-31 were prepared, using a conversion efficiency of 40%.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

PMM&Co. based impact estimation on the estimates made by MATHEMATICA of the feasibility of implementing this bioconversion (or anerobic digestion) measure.

As the value of natural gas increases, the economics of bioconversion become more favorable. The additional incentive of tax credits (similar to the capital investment allowance) and accelerated depreciation (similar to that for new rental housing construction) would probably enhance implementation of this measure somewhat beyond MATHEMATICA's feasibility estimation.

IMPACTS

A summary of impacts is shown in Figure VI-14.

Private Consumer

If the gas utilities passed on the operating savings, the consumers could receive a very small cost saving of approximately $14.2 million cumulative between 1977 and 1990. (This assumes 20 percent of the gas produced goes to residential use.

In addition, the bioconversion process should provide valuable byproducts for use in the food industries (e.g., protein). There would be both a financial and employment stimulation (not estimated) as a result of process byproduct development.

FIGURE VI-13

ENERGY SAVING, BIOCONVERSION OF SOLID WASTE TO FUEL FOR POWER GENERATION

YEAR	SOLID WASTE CONVERSION POTENTIAL (10^{12} BTU)	PER CENT OF SOLID WASTES INPUT TO ANEROBIC DIGESTER*	SOLID WASTES DIGESTED (10^{12} BTU)	GAS EQUIVALENT (10^{12} BTU)
1977	1110	Negligible	0	0
1980	1240	.5	6.2	2.5
1985	1530	3.0	45.9	18.4
1990	1870	7.8	146	58.4

Source: MATHEMATICA, Inc.

*Implementation schedule assumes same implementation pattern as was used for direct firing, however with 10 year lag.

FIGURE VI-11

BIOCONVERSION IMPACT SUMMARY

	Annual Impact				Cumulative Impact
	1977	1980	1985	1990	
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	0	2.5	18.0	58	247
2. Estimated Feasible	0	2.5	18.0	58	247
B. Impacts (Millions of Dollars)					
1. Private Industry					
Gas Retailer/Producer	0				
Revenue Increase		$0.9m	$7.2m	$23.2m	$98m
Operating/Capital Cost		($0.7m)	($5.2m)	$17m)	($71m)
2. Private Consumer Saving	0	$ .04m	$ .4m	$ .32m	$ 5.4m
3. Public Sector					
Government		Not Estimated			
Balance of Payments	0	$ .01m	$ .1m	$ .32m	$ 1.9m
4. Employment (Jobs)		Insufficient Data			
5. Environment (Percent Reduction)					
Solid Waste		.067%	.44%	1.34%	

Public Sector

The other public sector impact would be a slight import reduction of natural gas estimated at $1.4 million by 1990. The savings would be due to U.S.'s reduced imports of gas, which are presently only 1.4% of total demand.[1]

Quality of Life

Quality of life impacts should be nonexistent for implementation of this bioconversion measure, since it deals only with a technological problem of producing power through an alternate means, not a reduction of power.

Scarce Materials/Resources

Biological conversion of organic materials for power generation will serve to utilize the heat content of materials which otherwise might be discarded. Oil and natural gas, as well as coal, used for power generation can be conserved.

In addition, biological conversion residues are valuable byproducts that can be turned into protein, and thus, enhance the food supply. Work at Natick Laboratories,[2] among other places, has demonstrated the food potential of such organic residue.

Some problems could occur in obtaining adequate supplies of the various exotic materials used to make "molecular sieves" for bioconversion process equipment, but these problems should not be major.

Environment

Bioconversion of solid wastes into methane can have positive air and solid waste pollution impacts. Bioconversion can take place with minimal pollution problems, although odor problems can result if bioconversion equipment is not properly maintained.[3]

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[1] Citizens Action Guide, op.cit.

[2] Osterling, 1970.

[3] Private Communication, Los Angeles County Sanitation Department, Methane Conversion Project.

Since fairly pure methane is produced in bioconversion, use of this gas for power generation could serve to reduce fossil fuel pollutants. Using SO_2 as a pollutant reduction guide (since power generation is responsible for half of all SO_2 emissions), it can be estimated that this measure would be responsible for only a 2.84 million-pound reduction of SO_2 pollutants and .0049% of all SO_2 emissions. The reduction in SO_2 would increase, however, to 19.2 million pounds by 1985. By 1990, a cumulative 56.9 million-pound reduction in SO_2 would mean that about 0.12% of all SO_2 emissions would be reduced through bioconversion. These effects are quite small.

Bioconversion eliminates only a part of the organic solid waste it uses; while the residue can pose a problem, it also has food uses, as discussed under the "Private Consumer" and "Scarce Materials Resources" sections for this measure.

Bioconversion could eliminate .139 million tons of solid waste (.067% of the solid waste stream) by 1980, with a reduced landfill demand of .55 million cubic yards. By 1985, one million tons (.44%) of solid waste could be eliminated, with a reduced landfill demand of approximately 3.98 million cubic yards. These reductions would rise to .354 million tons (1.34%) of eliminated solid waste and 13.0 million cubic yards of landfill demand by 1990.

Private Industry

The bioconversion of solid waste to produce methane gas will, as with pyrolysis, replace sales of natural gas. As natural gas is currently production-limited, the effect of additional methane availability will be to increase the revenues of gas utilities by a cumulative amount of $98 million based on current natural gas prices.[1] However, these revenues will be offset by the increased capital and operating costs of producing the methane, which has been estimated to be \$.31 million/BTU.[1] This cost would be reduced by the 7 percent tax credit and depreciation allowance. The total-offsetting cost would be \$76 million for a net savings of \$27 million to the gas utilities.

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[1] Technology Review, 1974

The above analysis suggests that bioconversion at current technology levels, prices of natural gas, and construction costs, is more economical than pyrolysis which resulted in a net increased cost of production.

Employment

The bioconversion process should create new jobs in equipment manufacture and operations. Data were not available to estimate the probable employment impact.

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[1] Dugos, 1973.

G. WASTE HEAT RECOVERY

1. Maximum Energy Savings

In 1972, approximately 14,900 trillion BTU of fossil fuel were used to produce 1.42 trillion Kwh of electricity or 4850 trillion BTU_e[1]. Slightly over 10,000 trillion BTUs of thermal energy was rejected to the environment as waste heat. This section provides estimates of the amount of that waste heat that can be recovered.

AEC in cooperation with HUD conducted a comprehensive study of the potential use of waste heat.[2] AEC considered the following applications as potential candidates:

- space heating and cooling;
- water heating;
- sewage distillation;
- industrial process heat;
- mass transit;
- snow melting; and
- greenhouse heating and cooling.

In this study, both industrial process heating and residential heating and cooling were considered as potential users of waste heat. Factors considered important in estimating potential recoverability of waste heat were:

- siting; steam can only be transmitted over relatively short distances as compared to fossil fuels or electricity.
- availability; plant operations are scheduled to meet the demands of the electrical grid and not thermal requirements. Availability considerations might exclude all but base loaded plants from any "thermal grid".

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[1] EEI, 1973.

[2] Miller, et al, 1971.

- costs; the incremental cost of equipment for energy recovery and transmission lines must be covered by the revenue from selling steam and the savings resulting from elimination of some of the heat rejection system.

Based on the above criteria, AEC concluded that energy recovery from a 1000 MW_e power plant was feasible for a new city with a population of 200,000 to 400,000 people or more.

We shall first estimate the total waste heat available and then consider potential applications.

The fuel demand projections shown in Appendix A can be used to estimate total potential waste heat available. Based on a national average heat rate of 10,479 BTU/Kwh,[1] fossil fueled power plants have an average efficiency of 32.6% with 67.4% of input energy being rejected as waste. However, not all this energy is available[2] as only about 50% of waste heat input can usually be recovered.

The heat rate for nuclear plants is a function of the reactor technology. Rejected energy from nuclear fueled power plants range from 67.4% to 76.3%[3], with an average of 71.8% used in this report. Again only 50% is considered recoverable. These recovery estimates and electrical generation estimates as shown in Figure VI-2 were used to estimate total recoverable waste energy (Figure VI-15). Retrofit was eliminated as a viable alternative, as veing expensive and presenting engineering difficulties. Therefore, only incremental generation was considered, with 1977 taken as the baseline.

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[1] EEI, 1973.

[2] HUD, 1973.

[3] E. Miller, et al, 1971.

FIGURE VI-15

POWER GENERATION RECOVERABLE WASTE HEAT

(1977 Base Year)

(Without Turbine Extraction)

YEAR	FOSSIL FUEL		NUCLEAR POWER		TOTAL ENERGY AVAILABLE $(10^{12}\ BTU_t)$
	INCREASE IN FUEL REQUIREMENTS $(10^{12}\ BTU_t)$	WASTE HEAT AVAILABLE $(10^{12}\ BTU_t)$	INCREASE IN ENERGY GENERATED $(10^{12}\ BTU_e)$	WASTE HEAT AVAILABLE $(10^{12} BTU_t)$	
1977	-	-	-	-	-
1980	682	341	1186	2103	2444
1985	1279	640	4795	8502	9142
1990	1389	694	9230	16360	17050

Source: MATHEMATICA, Inc.

In utilizing waste heat, while both industrial and residential users were considered, industrial use was given first priority. This was done because of the savings associated with a single user, avoiding district heating systems. The AEC study considered six manufacturing groups as potential users of waste heat. These six and their SIC Codes are food and kindred products (20), paper and allied products (26), chemical and allied products (28), petroleum refining and related industries (20), rubber and miscellaneous plastic products (30) and textile mills (22). These six industries were selected as being the manufacturers with the largest steam demands. AEC reported a demand of 5040 trillion BTU for 1962 and estimated a demand of 10,600 and 12,200 trillion BTU for 1980 and 1985, respectively.

More recent estimates using the 1972 Census of Manufacturing data[1] shows that these six groups required 57% of industrial fuel, the equivalent of 1.91 trillion Kwh of electric energy or 6519 trillion BTU_t in 1971. Boiler efficiencies are estimated to be 70% at best. Therefore, it is estimated that these six groups required 4563 trillion BTU_t as steam for 1971. In estimating steam demand, incremental consumption was considered. Consumption estimates were derived from TERA[2] and Figure VI-16 reports potential energy savings in these six SIC groups, and only new fossil fuel demand was included.

Steam requirements are generally low grade. Based on AEC data; approximately 96% is below 450 psig, and 72% is below 150 psig. While higher quality steam can be extracted directly from turbines to satisfy prime industrial demands, only demands

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[1] Department of Commerce, 1973, B.

[2] AGA, 1974.

FIGURE VI-16

WASTE HEAT RECOVERY FOR USE IN INDUSTRIAL SECTOR - POTENTIAL ANNUAL SAVINGS

YEAR	INCREASE IN TOTAL FOSSIL FUEL DEMAND (10^{12} BTU_t)	INCREASE IN FOSSIL FUEL DEMAND BY 6 MAJOR USERS (10^{12} BTU_t)	INCREASE IN STEAM GENERATED (10^{12} BTU_t)	INCREASE IN ENERGY REQUIRED BELOW 450 psig
1977	0	0	0	0
1980	1356	773	541	519
1985	4691	2674	1871	1796
1990	8026	4575	3202	3074

SOURCE: MATHEMATICA, Inc.

below 450 psig were assumed to be satisfied, reducing the need for very high temperature and pressure lines over great distance. Therefore, only 96% of industrial demand was considered capable of being satisfied by power generation waste heat. While none of the industrial demand could be met by waste heat in 1977, all new industrial demand (less 4% very high quality steam) could be satisfied in the 1980s under the assumption that new industrial demand was favorably located with respect to new power plants.

Waste heat can also be utilized for residential heating and cooling. The Total Energy System and district heating are prime examples of that application. For example in 1968, 44 district heating companies sold over 84.2 billion pounds of steam of a total of 96.7 billion pounds delivered. Based on an average energy content of 1200 BTU/pound, the total equivalent of 116 trillion BTU of steam was delivered in 1968. However, only about 960 BTU per pound is recoverable; therefore, only 80.8 trillion BTU of usable energy was delivered. The energy is delivered to a variety of users including homes, offices, industries and institutional users, with commercial users purchasing the bulk of the available energy.

Limiting residential applications to "townhouses" as a minimum density, annual gas and oil energy requirements were estimated on a regional basis[1]. This data, originally reported for use in evaluation of Total Energy Systems, considered housing complexes in the range of 100 to 3,000 dwelling units. The total average demand for either natural gas or No.2 oil was .177 trillion BTU per dwelling unit.

Estimated multi-family or townhouse residential demand for energy and oil from post 1977 new construction is shown in Figure VI-17. Again, no fossil fuel savings are shown for 1977;

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[1] HUD, 1973.

FIGURE VI-17

POTENTIAL ANNUAL RESIDENTIAL DEMAND FOR RECOVERED STEAM

YEAR	POPULATION (millions)	FRACTION IN URBAN AREA	FRACTION IN MULTI-FAMILY DWELLINGS	URBAN POPULATION IN MULTI-FAMILY UNITS (millions)	DWELLING UNITS (millions)	INCREASE IN DWELLING UNITS (millions)	INCREASE IN FOSSIL FUEL ENERGY DEMAND FROM 1977 (10^{12} BTU)	EQUIVALENT STEAM DEMAND (10^{12} BTU)
1977	219.7	.771	.53	89.8	42.8	-	-	-
1980	226.9	.786	.55	98.1	46.7	3.9	690	482
1985	239.3	.813	.58	112.8	53.7	10.9	1930	1350
1990	250.5	.840	.60	126.3	60.1	17.3	3060	2140

Source: MATHEMATICA, Inc.

however, for post 1977, energy savings are possible. Total fossil fuel savings in residential and industrial sectors is estimated in Figure VI-18. The ratios of steam required to displace the fossil fuel demand to the steam available in 1980, 1985 and 1990 is .68, .53, and .50 respectively. It appears reasonable to assume this demand can be satisfied. A penalty is shown to account for reduction in fossil fuel turbine efficiency for high temperature steam removal.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

Quantifiable feasibility factors have been taken into account for the maximum energy savings estimates. Based on the estimated cumulative energy savings possible from 1977 to 1990 would be 46,486 Trillion BTUs.

There are approximately a dozen installations currently in operation around the country with major heat recovery operations.[1] Waste heat recovery techniques in conventional incinerators have already been demonstrated in the United States and abroad; techniques using high-temperature incinerators have been developed but not yet demonstrated adquately.[2]

The implementation strategy for the waste heat recovery measure was the same as the first three measures in that power generation sector: federal and/or state tax credits and special depreciation rates for waste heat recovery equipment. At least one government-sponsored study[3] has indicated the potential economic feasibility of waste heat recovery systems based simply on rising electricity and heat costs; tax incentives would probably serve to enhance the economic attractiveness of the measure.

One additional siting factor in the case of nuclear-powered plants would have to be the extra safeguards to ensure uncontaminated steam recovered from the plants.

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[1] EPA, 1974.

[2] Miller, *et al*, 1971

[3] ORNL-HUD, 1971.

FIGURE VI-13
TOTAL FOSSIL FUEL SAVING

WASTE HEAT RECOVERY

(10^{12} BTU)

YEAR	INDUSTRIAL (96% of Industrial Demand)	RESIDENTIAL	TOTAL EQUIVALENT FOSSIL FUEL DEMAND	PENALTY FOR TURBINE EXTRACTION (FOSSIL FUEL)	NET GAIN
1977	0	0	0	0	0
1980	741	690	1431	19	1412
1985	2566	1930	4496	36	4460
1990	4391	3060	7451	36	7415

Source: MATHEMATICA, Inc.

IMPACTS

A summary of impacts is shown in Figure VI-19.

Private Consumer

No direct impacts have been assumed. However, there is a potential financial impact that would result from new space heating equipment used in new home construction. Insufficient data was available to estimate the potential added cost or savings associated with the system.

Public Sector

Public sector costs are estimated at $90 million lost tax revenues from a 7 percent investment tax credit. Depreciation allowances are not estimated.

Public sector savings from the utilization of waste heat wuld be approximately $1.3 billion in reduced natural gas and oil imports, resulting from reduced domestic consumption of gas and oil.

Quality of Life

Quality of life impacts should be nonexistent for implementation of the waste heat recovery measure, since it deals with a technological problem of producing power through an alternate means, not a reduction of power.

Scarce Materials/Resources

Recovery of waste heat involves two major problems in the scarce materials area:

- The design of highly efficient heat-conducting materials for specific applications can be a sophisticated problem; and
- the demand for corrosion-resistant materials would increase since corrosion is usually a troublesom factor in heat recovery processes.

These factors should not, however, be major stumbling blocks to implementation.

FIGURE VI-19

WASTE HEAT RECOVERY IMPACT SUMMARY

	Annual Impact 1977	1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	0	1,412	4,460	7,415	46,868
2. Estimated Feasible	0	1,412	4,460	7,415	46,486
B. Impacts (Millions of Dollars)					
1. Private Industry					
Power plant revenues from sale of steam		$2,952m	$9,275m	$15,376m	$98,088m
Annualized Capital Cost of Power Plants	0	($2,046m)	($6,450m)	($10,698m)	($70,479m)
Added Operating Cost			Insufficient Data		
2. Private Consumer			Not Applicable		
3. Public Sector					
Government	0		Not Estimated		
Balance of Payments	0	$38.7m	$121.7m	$201.8m	$1,288m
4. Employment (Jobs)			Insufficient Data		
5. Environment					
Thermal Pollution (BTUx10^{12}) Reduced	0	1,412	4,460	7,515	
SO_2 Emissions (Percent Reduction)	0	2.7%	6.1%	9.1%	

* Assumes added operating costs equivalent to fuel costs avoided.

Environment

The magnitude of energy savings possible through waste heat recovery in power generation is indicative of the reduction in thermal pollution possible from implementation of this measure, since 52.6% (10% stack heat loss not included) of the energy in electrical power generation ultimately becomes thermal pollution.[1] Hence, a reduction in thermal pollution of 830 trillion BTUs is possible by 1980, while this figure climbs to 2,310 trillion BUTs by 1985, and 3,810 trillion BTUs by 1990.

Air pollution reduction - indicated by the SO_2 reduction possible through implementation of this measure - would be very significant. A 1,580 million-pound reduction of SO_2 by 1980 is possible; this represents a reduction in SO_2 emissions from power generation of 4.72% and a reduction in total SO_2 emissions of 2.7%. By 1985, these figures climb to 4,669 million pounds (10.5% and 6.1%). By 1990, implementation of this measure could mean that [illegible],120 million pounds of SO_2 could be removed from the air: a decrease of 14.8% of SO_2 emissions from power plants, or an overall decrease of 8.1% in all SO_2 emissions.

Private Industry

The use of waste steam heat from power plants will displace sales of fossil fuels, i.e., oil, gas, and coal. These fuels, normally used to provide space heating and hot water, would be replaced by steam. At current prices, total value of fossil fuels replaced could reach $98.0 billion by 1990.

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[1] Hittman, 1973.

Based upon Miller's figures for the peak heat loads of excess heat which could be sold by a 1000-megawatt plant equipped for selling district sector (residential) and industrial heat,[1] it would require cumulative annualized capital expenditures of $70 billion by 1990 to deliver the steam energy to residential and industrial users.

Assuming commercial and residential buyers would not pay more for energy, the power plant's increased capital and operating costs would be offset by an amount equivalent to the cost of replaced fossil fuels. It must be kept in mind, however, that as the price of fossil fuel increases, the economics of waste heat sales could change and show either increased profits ofr the sellers of waste heat or savings for waste heat energy consumers.

Indirect impacts would be reflected by added inudstrial activity associated with development of heat recovery facilities and transmission lines. On the other hand, declines in the demand for industrial and residential heating units could be anticipated. Detailed data from which to quantify these effects are not available.

Employment

New jobs would be created in the design, construction, operation, and maintenance of the steam generation and distribution facilities. A number of jobs might be eliminated in the conventional heating/cooling industry. Available data does not permit estimation of the magnitude of these effects.

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[1] Miller, et al, 1971.

H. WIND ENERGY

1. Maximum Energy Savings

The study of wind energy is also the objective of considerable NSF research. However, to date, the research has lacked overall direction, with concept demonstrations capitalizing on fortuitous local wind conditions[1] or proposals being put forth to capture known high potentials such as offshore winds on the Pacific Coast[2] or off New England.[3]

Several investigations have been conducted in the past to determine the feasibility of aeromotive wind utilization over relatively large geographic areas, most notably reported by Percy Thomas[4] of the U.S. Federal Power Commission and Golding and Stodhart[5], under the auspices of the British Electrical and Allied Industries Research Association. These studies attempted to summarize available wind data in terms of mean velocity, geographical distributions, statistical wind persistence, and other pertinent investigative results to show the existence of favorable wind regimes and regional sites which could economically justify large scale wind energy utilization projects. Thomas' work went to the greatest extent in this respect by utilizing 50 widely dispersed weather stations in the continental United States with record histories ranging from 12 to 31 years. The British studies used 20 Air Ministry observing stations to characterize the wind over the British Isles.

Additional research has been conducted into the general problems of developing models of wind as a function of height, local topography, and major geologic features[6].

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[1] Putman, 1948.

[2] Hewson, et al, 1973.

[3] Dambolena, et al, 1974.

[4] Thomas, 1945.

[5] Golding, 1949, and Golding & Stodhart, 1952.

[6] Hewson, 1973.

Several pertinent measurement programs and analyses have recently been performed related to the statistical persistence of high winds, short-term fluctuations and vertical distributions of wind flows, and long-term observations of offshore surface meteorological conditions. The Environmental Data Service National Climatic Center has recently developed a computer program and has published climatical summaries of durations of high surface winds in the Great Lakes area.[1]

While the various previous wind energy investigations provide a large amount of valuable background information, it is recognized that no detailed national scale estimates of wind energy potential for the United States exist. Moreover, significant efforts and analytical extensions of prior work will be required to produce a regional level assessment by potential user exhibiting the detail and accuracy needed for in-depth analyses leading to ultimate wide-scale utilization.

The ability to capture wind energy is dependent on the characteristics of the hardware, such as rotors and controls, the ability to site towers in the most favorable wind regimes, and even the ability to modify low level wind characteristics to improve system performance. This study does not consider wind energy systems at that level of detail, but does instead focus on the process of development and commercialization of large scale systems.

Once we have a mechanism for extracting mechanical energy from the wind, the next step is to transform that energy into a useful form with respect to particular applications. While windmills are popularly thought of as producers of mechanical energy, most studies of wind energy at the national level have focused on the eventual transformation of kinetic wind energy to electric power.

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[1] EDS, 1972.

Much of the research has concentrated on the development of variable speed constant frequency generating systems, control systems which will allow the wind system to be coupled to synchronous generators, or through the conversion of energy to an intermediate medium such as d.c. electric power,[1] compressed air or pumped hydrostorage. However, in this project we are only concerned with power generation.

A mechanism for inexpensive and efficient storage of energy once it has been extracted from the winds has been identified as the component, necessary to any large scale application of wind energy. Two distinct storage requirements exist. The first of these is "long term" and consists of developing energy storage capacity equal to the projected demand for extended periods during which the wind is below the windmill cut-in threshold.[2] Most studies have considered a four day storage capability as necessary and current research is investigating pumped hydro electric storage, compressed air,[3,4] electrolysis coupled with fuel cells[5] or even the use of hydrogen itself as a fuel,[6] as solutions to this problem.

A second short term storage requirement originates in the fact that in some applications such as remote rural use or residential peaking, the average daily demand profile will not coincide with the average daily energy supply profile. Some short term storage of energy will be required to bridge diurnal energy shortages. Various devices suggested for short term storage include molten salts, hot water, hot rocks, batteries and flywheels. Tying a wind generator to the electrical energy grid might be one additional answer to this short term storage problem.

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[1] [illegible], 1973.

[2] Cut-in threshold is that speed below which the rotor and energy conversion equipment cannot operate effectively.

[3] Swanson, et al, 1974.

[4] Meyer, 1973.

[5] Dambolena, 1974

[6] Gregory, et al, 1972.

In the above paragraphs we have briefly touched on the state of the art in wind energy systems. There are major areas which we have not discussed, such as towers, control systems and rotor configuration. We feel that the commercial development of wind energy systems requires considerable research and development. Estimates by experts[1] and even as reported in the Congressional Record[2] indicate a period of 5 to 7 years before the viability of a large system (10 MW) is established.

Based on information available in the literature cited above, a scenario for wind energy development was developed (Figure VI-20). Ten 100 MW_e systems are anticipated for 1985. Each system will be a different application and is intended to demonstrate the validity of the concept in that application.

MATHEMATICA views an application as being defined by three parameters: (1) the type of output or process utilized to capture the wind energy, (2) the type of use to which this energy is applied, and (3) the type of user. Based on some preliminary analysis as depicted in Figures VI-21 and VI-22, we have identified ten types of output, five types of use and twelve users. Taking simple combinations of these parameters results in an extremely large number of applications even though the bulk of them may not be feasible. If multiple points are allowed, such as a combination of base loading for utility grid and local peaking, then the number of alternatives becomes even larger.

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[1] NSF/NASA, 1973.

[2] Humphrey, 1974.

FIGURE VI-20

WIND ENERGY DEVELOPMENT SCENARIO

YEAR	MAXIMUM SYSTEM SIZE	MAXIMUM NUMBER	TYPE	MW_e IN PLACE	Output 10^6 kWh
1979	10 MW_e	1	Developmental	10 MW_e	61.3
1981	100 MW_e	1	Developmental	100 MW_e	61.3
1985	100 MW_e 500 MW_e	10 1	Test of Different Application Developmental	1500 MW_e	92.03

Source: MATHEMATICA, Inc.

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FIGURE VI-21

[illegible]

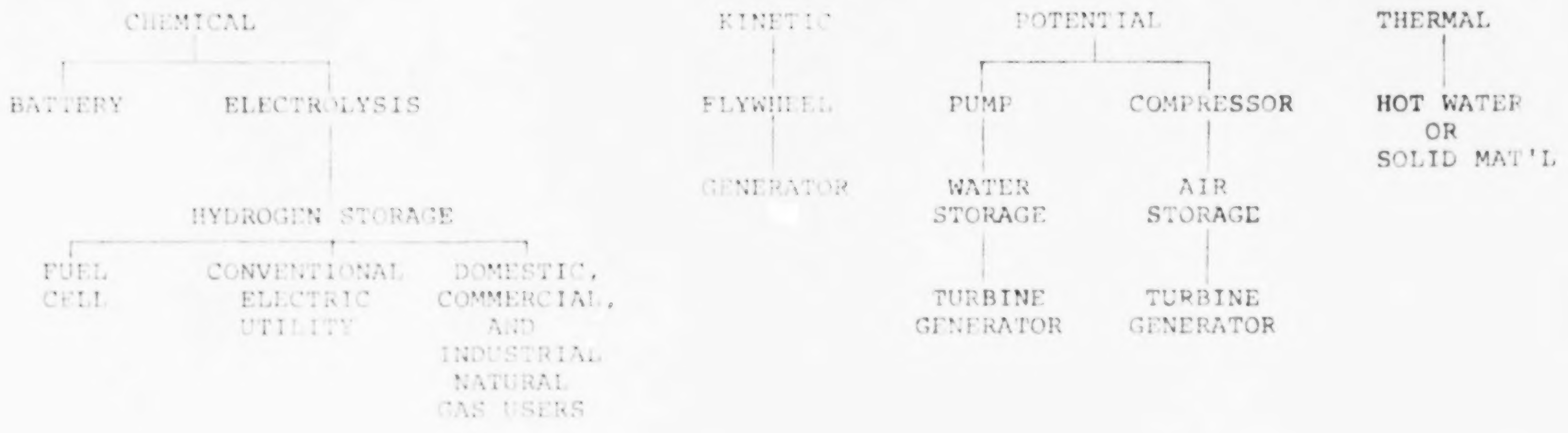
[illegible]	User	Use	Motivation*
Magn[illegible] 1. [illegible] 2. [illegible] Direct* [illegible] Industrial Process [illegible] [illegible] Heating 1. [illegible] 2. [illegible]	[illegible] 1. Municipal 2. Group 3. Investor Owned 4. Federal (Regulatory) 5. Other 6. [illegible] District Nonutility 7. [illegible] 8. Private Site- [illegible] 9. Rural Communities 10. Industrial Parks 11. Mines 12. Irrigation Systems	Utility 1. Base Load 2. Intermediate Load 3. Peaking Nonutility 4. Primary on-site Power 5. Supplemental Power (Selective Energy System)	Fuel Costs-Capital and Operating . Unavailability of alternative fuels . Conservation of [illegible] Fuels

*[illegible] as an additional dimension in the definition of an application.

Source: MATHEMATICA, Inc.

FIGURE VI-22

STORAGE PROCESSES


CHEMICAL
BATTERY
ELECTROLYSIS
HYDROGEN STORAGE
FUEL CELL
CONVENTIONAL ELECTRIC UTILITY
DOMESTIC, COMMERCIAL, AND INDUSTRIAL NATURAL GAS USERS
KINETIC
FLYWHEEL
GENERATOR
POTENTIAL
PUMP
WATER STORAGE
TURBINE GENERATOR
COMPRESSOR
AIR STORAGE
TURBINE GENERATOR
THERMAL
HOT WATER OR SOLID MAT'L

Source: MATHEMATICA, Inc.

It is estimated that after demonstration of the 10MW$_e$ system in 1979, there will be a maximum of ten applications investigated in greater detail, although a more likely number is 4 or 5.

Figure VI-23 combines previous projections of electric energy generation with wind energy estimates to estimate percentage of incremental demand satisfied by wind. By 1985 approximately .7% of new electrical demand will be supplied by wind. Thus wind systems can be considered as proved technology at that date and we assume that by 1990 3% of incremental demand can be met by wind (Figure VI-24).

FIGURE VI-23

INCREMENTAL DEMAND SATISFIED BY WIND

YEAR	ELECTRIC DEMAND (10^{12} BTU)	INCREASE IN DEMAND OVER PREVIOUS PERIOD	WIND SYSTEM IN PLACE IN PERIOD (10^{12} BTU)	PERCENT OF NEW DEMAND SUPPLIED BY WIND
1977	9410	-	0	0
1980	11327	1918	.52	.03
1985	15500	[illegible]	31.4	.74

Source: MATHEMATICA, Inc.

FIGURE VI-24

WIND ENERGY POTENTIAL

YEAR	PERCENT OF NEW DEMAND	NEW DEMAND $(10^{12}$ BTU)	WIND ENERGY $(10^{12}$ BTU)	TOTAL CAPACITY $(10^{12}$ BTU)
1977	0	-	-	-
1980	.03	1910	.52	.52
1985	.74	4210	31.4	31.9
1990	3.0	4550	136.5	168.4

Source: MATHEMATICA, Inc.

2. Achievable Energy Savings and Impacts

ENERGY SAVINGS REALIZATION

Because MATHEMATICA estimates of possible energy savings through the use of wind energy were based on the technical and logistical feasibility of the measure, PMM&Co. has used a 100 percent realization of possible savings. Thus, from 1977 to 1990, 581 Trillion BTUs would represent the cumulative savings due to wind energy.

Until fiscal year 1973, relatively little government funding had been appropriated for the development of wind power, even though this and other varieties of solar energy appeared technologically promising. In FY 1973, the Wind Energy Conversion Systems Program was established as part of the Solar Energy Program at the National Science Foundation. The wind energy program, which received $200,000 its first year, and $1,500,000 the second, has a five-year program plan to sponsor workshops and provide grants for experimental wind power systems and research on economic and feasibility issues.

According to the director of the NSF wind program, one of the major problems hindering greater development in this area is the high initial capital investment required for wind systems. Therefore, an implementation strategy which includes government loan assistance for capital equipment would make the cost of wind systems much more attractive.[1]

In the area of related legal precedent, Senate bill 3234 on solar energy research, which was reported out of conference in October 1974, includes a provision for specific federal support for wind energy research, data collection, and demonstration projects. A new law (Pl. 93-409) was also passed in September which sponsors only solar heating and cooling demonstration projects; this law provides no additional funds for wind research.

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[1] Private communications, Director of Wind Energy Conversion Systems, Solar Energy Program, National Science Foundation.

Tax credits and accelerated depreciation, however, are already offered by the IRS for other types of capital equipment investments.

IMPACTS

A summary of impacts is shown in Figure VI-25.

Private Consumer

Assuming an average of 20 percent consumption of electric power by the private consumer, and assuming power companies would pass along added costs, consumers would pay approximately $38.8 million more for electric power in 1990. Between 1980 and 1990 the cumulative added cost would be $142.4 million.

Public Sector

Displacement of oil consumption could result in a decrease of $44.9 million in import costs. It has been assumed that gas and coal imports would not be affected.

Quality of Life

Quality of life impacts should be nonexistent for implementation of this measure, since there is only a technological problem of producing power through an alternate means, not a reduction of power.

Materials/Resources

No materials/resource problems are anticipated.

Environment

The use of wind power for power generation can reduce thermal and air pollution emissions, since it is a totally nonpolluting energy source. Its positive environmental impacts, however, will be minimal until 1990, and rather small even then. The thermal pollution reductions possible are .274 Trillion BTU in 1980, 17.5 Trillion BTU in 1985, and 70 Trillion BTU in 1990. SO_2 reductions possible through implementation of this measure are .274 million pounds of emissions from power generation and .0013% of all emissions, 33.4 million pounds in 1985 (0.748% of power generation emissions and .044% of all emissions) and 132.2 million pounds by 1990 (0.276% of SO_2 emissions from power generation and 0.153% of all SO_2 emissions).

FIGURE VI-[illegible]

WIND ENERGY IMPACT SUMMARY

	1977	Annual Impact 1980	1985	1990	Cumulative Impact
A. Energy Savings (BTUs x 10^{12})					
1. Maximum	0	0.52	31.4	137	501
2. Estimated Feasible	0	0.52	31.4	137	501
B. Impacts (Millions of Dollars)					
1. Private Industry					
Power Company Added Cost	0	($0.8m)	($50.2m)	($218m)	($801m)
2. Private Consumer		($.16)	($10m)	($44m)	($160m)
3. Public Sector					
Government		NOT ESTIMATED			
Balance of Payments	0	$.05m	$2.8m	$12.2m	$45m
4. Employment (Jobs)					
5. Environment					
Reduced Thermal (BTU x 10^{12})	0	.274	17.5	70	
SO_2 Emissions (percent reduction)	0	.0013%	.044%	.153%	

William E. Heronemus, the leading U.S. wind power advocate, envisions chains of windmills stretching across the Great Plains from the Texas coast to the Canadian border.[1] An earlier plan would have meant building over 350,000 850-foot towers, each bearing 20 turbines. A revised land-conserving version proposed by Heronemus entails building 800-foot posts straddling highways at half mile intervals with the turbines slung from cables in between. Others have proposed building windmill farms in the ocean to circumvent the significant aesthetic and land use problems associated with wind power. It is apparent that these factors could have significant negative environmental impacts in wind power production.

Private Industry

The generation of electricity from wind energy would impact the electric utilities. A study was made on a system to be located off the New England coast which would supply 160 billion KWH/year by 1990.[2] The designers of the system estimate the operating and capital cost of electricity produced would be $.0216/KWH. However, Ernest W. Peterson of Oregon State University estimates cost at $.0941/KWH.[3] For purposes of the analysis, the optimistic cost of $.0216/KWH has been assumed.

Industry impact estimates are based upon the assumption that the amount of wind generated would equal the amount of fossil fuel energy displaced, i.e., no conversion loss has been assumed. Assuming average electric power production costs of \$.005/KWH[1] (using conventional generating technology), wind generated electricity would cost an additional \$.0166/KWH. Total added cost for 1990 production would be \$218 million. Cumulative added cost between 1980 and 1990 is estimated at \$801 million. Approximately \$1.2 billion in fossil fuel costs would be avoided during this period.

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[1] Wade, 1974.

[2] Dambolena, *et al*, 1974.

[3] Peterson, 1974.

Employment

New jobs would be generated in the development, construction, installation, and operation of wind power systems. Sufficient data are not available to allow estimates of these employment impacts.

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[1] FPC, 1972.

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